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Municipal Waste Combustion Study
Combustion Control of Organic Emissions

Energy and Environmental Research Corp.
Irvine, CA

Prepared for

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This report discusses the combustion practices expected to result in decreased emissions of organic compounds from municipal waste combustion facilities. The objectivies of this study were:

1. To determine the currrent state of combustion control of municipal solid waste combustion technology;

2. To formulate a combustion control strategy based upon "best engineering practice" that will minimize the emission of trace organics from waste-to-energy plants;

3. to define the research which is necessary to develop and verify this combustion control strategy.

Although the focus of this study was concerned with the best combustion practices which will minimize the emissions of organics, including polychorinated dibenzo(p)dioxin and furans (PCDDs/PCDFs), the interrelationship with other pollutants such as particulate matter , metals, NOx, other organics, and carbon monoxide was also considered. The study focused on the design of new units and the operation and monitoring of new and

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existing units from the viewpoint of the combustor/boiler subsystem. The report discusse current technolgies for mass-burn refuse- derived -fuel, and starved-air combustions, and the strategies for achieving improved combustion from these technologies.

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8. To describe control systems operated by the facilities tested and present available control efficiency data for each facility tested.

EPA/530-SW-87-021B

EMISSION DATA BASE FOR MUNICIPAL WASTE COMBUSTORS

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1. INTRODUCTION

This volume is a compilation of emission data for municipal waste combustors (MWC's). The information presented herein was developed during a comprehensive, integrated study of municipal waste combustion. An overview of the findings of this study may be found in the Report to Congress on Municipal Waste Combustion (EPA/530-SW-87-021A). Other technical volumes issued as part of the municipal waste combustion study include:

- Combustion Control of Organic Emissions (EPA/530-SW-87-021C)
- Flue Gas Cleaning Technology (EPA/530-SW-87-021D)
- Costs of Flue Gas Cleaning Technologies (EPA/530-SW-87-021E)
- Sampling and Analysis of Municipal Waste Combustors (EPA/530-SW-87-021F)
- Assessment of Health Risks Associated with Exposure to Municipal Waste Combustor Emissions (EPA/530-SW-87-021G)
- Characterization of the Municipal Waste Combustion Industry (EPA/530-SW-87-021H)
- Recycling of Solid Waste (EPA/530-SW-87-021I)

This volume also responds in part to a settlement agreement between the U. S. Environmental Protection Agency (EPA) and the State of New York and the Natural Resources Defense Council (NRDC). Pursuant to paragraph three of the Settlement Agreement in State of New York v. Thomas (No. 84-1472) and Natural Resources Defense Council v. Alm (No. 84-1473), before the U.S. Court of Appeals for the District of Columbia Circuit, EPA agreed to issue a document(s) that:

(a) identifies, to the extent data are available, the lowest emission levels of organic compounds (including dioxins), metals, acid gases, and particulate matter that have been achieved from MWC's on a commercial scale;

(b) identifies, to the extent data are available, the waste feed characteristics, operating conditions, and control techniques associated with such emission levels; and

(c) identifies available monitoring techniques (both sampling frequency and analytical methods) that can be used to determine whether emission levels from MWC's reflect the lowest emission levels achieved on a commercial scale.

The overall purpose of this volume of the Comprehensive Municipal Waste Combustion Report is to respond to sections (a) and (b) of paragraph three of the Settlement Agreement. To accomplish this purpose, an emission data base was compiled from test reports for MWC's in the U.S., Canada, Japan, and Europe. These emission data are presented in a format that allows comparison and analysis in order to identify, to the extent of available data, the lowest emission levels of organic compounds (including polychlorinated dibenzo-p-dioxin [PCDD] and polychlorinated dibenzofuran [PCDF]), metals, acid gases, and criteria pollutants that have been achieved from MWC's on a commercial scale. Table 1-1 lists the pollutants of concern for which data were compiled. The available operating conditions and control techniques associated with the lowest emission level for each pollutant of concern are identified.

Extensive resources were used to collect and organize the data presented in this volume. Certain reports were not readily available. Calculations were required to convert the reported data into consistent units of measure. Correspondence with most of the facilities was necessary to collect additional information on the combustor and control equipment. This compilation of data is the first step in achieving the ultimate objective of relating equipment design and operating parameters to multipollutant emission levels (section (b) above).

The specific objectives of this volume are:

1. To compile all available U.S. and Canadian data on emissions of the pollutants of concern from MWC's;

2. To compile readily available European and Japanese emission data on the pollutants of concern from MWC's;

3. To reduce the test data into consistent units of measure and reference and present those data in a common format;

TABLE 1-1. LIST OF POLLUTANTS

Criteria pollutants

- Particulate matter (PM)
- Nitrogen oxides (NO_x)
- Sulfur dioxide (SO_2)
- Carbon Monoxide (CO)

Acid gases

- Sulfates (SO_3 or H_2SO_4)
- Hydrogen chloride (HCl)
- Hydrogen fluoride (HF)

Metals

- Arsenic (As)
- Beryllium (Be)
- Cadmium (Cd)
- Chromium (Cr)
- Lead (Pb)
- Mercury (Hg)
- Nickel (Ni)

Organic pollutants[a]

- Tetrachlorodibenzo-p-dioxin (TCDD)
- Tetrachlorodibenzofuran (TCDF)
- Pentachlorodibenzo-p-dioxin (PeCDD)
- Pentachlordibenzofuran (PeCDF)
- Hexachlorodibenzo-p-dixon (HxCDD)
- Hexachlorodibenzofuran (HxCDF)
- Heptachlorodibenzo-p-dioxin (HpCDD)
- Heptachlorodibenzofuran (HpCDF)
- Octachlorodibenzo-p-dioxin (OCDD)
- Octachlorodibenzofuran (OCDF)
- Sum of TCDD through OCDD
- Sum of TCDF through OCDF
- Total measured chlorodibenzo-p-dioxin
- Total measured chlorodibenzofuran
- Benzene
- Polychlorinated biphenyls (PCB)
- Chlorinated benzenes (ClB)
- Chlorinated phenols (ClP)
- Formaldehyde
- Benzo-a-pyrene (BaP)

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[a] For the chlorinated dibenzo-p-dioxins and chlorinated dibenzofurans, data are presented for total homologue groups (tetra through octa) and for specific isomers within those groups that have chlorine substituted in the 2, 3, 7, and 8 positions.

4. To identify the lowest reported emission levels (LREL's) for criteria and noncriteria pollutants;

5. To describe the design and operation of each facility tested and tabulate key design and operating parameters for the test periods to the extent information is available;

6. To identify and describe, as appropriate, sampling and analysis methods used with each test to the extent that this information is provided in the data reference;

7. To distinguish qualitatively those data in a "documented" test report from those data that were obtained from references with limited or no documentation; and

8. To describe control systems operated by the facilities tested and present available control efficiency data for each facility tested.

Emission data included within this study are from systems that combust municipal solid waste (MSW) on an "as generated" basis (mass burn and starved air) and those that fire refuse-derived fuel (RDF). Data are also included for systems both with and without energy recovery. Data are not included for facilities that normally cofire MSW with alternative fuels, although data were included from tests that involved cofiring during a portion of the test program (e.g., Mayport). Data are included for units controlled by electrostatic precipitators (ESP's), fabric filters (FF's), dry and wet scrubbing systems (with either ESP's or FF's), and cyclones (associated with other controls or used as the principal control system on older facilities).

Data were compiled from the published literature and specific source test reports. Test reports that contained metals or organics emission data were reviewed in detail. These reports also contain criteria pollutant emission data from many facilities with state-of-the-art control systems that are expected to generate low levels of criteria pollutant emissions. Because the criteria pollutant data base derived from these reports is reasonably consistent and is expected to represent lowest criteria pollutant emission levels, resources were not expended to locate and review test reports containing only criteria pollutant data. No additional testing was conducted by EPA as a part of compiling and analyzing the data. However, EPA recently has undertaken additional testing as a part of the Agency's overall MWC program. Table 1-2 is a summary matrix showing the 36 facilities for which test results were available from well-documented emission test reports. The matrix presents the facilities in groups according to type of combustor and type of air pollution control equipment and shows the classes of pollutants for which test data are available. Table 1-3 is a summary matrix for the 27 facilities for which test results were available with no documentation of incinerator operations or test methodologies. The data from the facilities identified in Table 1-3 are considered supplementary to the data from the facilities identified in Table 1-2.

To the degree possible, data on the combustor and air pollution control device design and operating conditions also were extracted from the test reports. However, the data generally were quite scarce. To supplement the data in the test reports, 27 requests for additional information were submitted to facility operators, but only two responses were received prior to completion of this report. Consequently, the design and operating data presented herein are still quite limited. The EPA intends to collect additional information about these facilities as a part of ongoing regulatory development studies.

The results presented in this report represent aggregated results from tests containing a minimum of three sampling runs except where noted otherwise. The use of aggregate averages rather than run-specific test data placed limitations on the analyses of relationships among emissions and process parameters; however, aggregate averages were deemed to be the best format for achieving the primary objectives of this report. Individuals desiring to conduct more comprehensive analyses of the data should consult the referenced test reports to obtain run-specific data.

The results presented in this report should be interpreted in view of the following limitations inherent to the scope as defined above.

1. Limitations concerning inconsistent objectives and scope among tests at different facilities. Because the emission tests were not conducted as part of a single, well-defined study, data often were not collected under comparable combustion conditions, and the effects of variables that were neither controlled nor measured are likely to be significant. Consequently, parametric analyses of the data base should be undertaken with caution.

TABLE 1-2. OVERVIEW OF EMISSION DATA BASE

Facility name	Test condition	Criteria pollutants	Acid gases	Metals	Organics
Mass burn[a]					
Waterwall[b]					
ESP[c]					
Baltimore, 1/85	Normal[d]	X			
Baltimore, 5/85	Normal	X		X	
Braintree	Normal	X		X	
Chicago	Normal	X		X	X
Hampton (1981)	Normal	X	X		X
Hampton (1982)	Normal	X	X	X	X
Hampton (1983)	Normal	X			X
Hampton (1984)	Normal	X			X
McKay Bay (Unit 1)	Normal	X		X	
McKay Bay (Unit 2)	Normal	X		X	
McKay Bay (Unit 3)	Normal	X		X	
McKay Bay (Unit 4)	Normal	X		X	
N. Andover	Normal	X		X	X
Peekskill (4/85)	Normal	X			X
Saugus	Normal	X			X
Tulsa (Unit 1)	Normal	X	X	X	X
Tulsa (Unit 2)	Normal	X	X	X	X
Umea, fall	Normal				X
Umea, fall	Low temp[e]				X
Umea, spring	Normal				X
CYC/FF					
Gallatin	Normal	X	X	X	
ESP/WS					
Kure	Normal	X	X	X	
SD/ESP					
Munich	MSW only[f]	X	X	X	
CYC/DI/ESP/FF					
Malmo	Normal	X	X	X	
WSH/DI/FF					
Quebec	110[g]	X	X	X	X
Quebec	125[g]	X	X	X	X
Quebec	140[h]	X	X	X	X
Quebec	200[g]	X	X	X	X
Wurzburg	Normal	X	X	X	X
SD/FF					
Marion County	Normal	X	X	X	X
Quebec	140[h]	X	X	X	X
Quebec	140 & R[i]	X	X	X	X
Refractory					
ESP					
Philadelphia (NW1)	Normal	X	X		X
Philadelphia (NW2)	Normal	X	X		X
CYC/ESP					
Washington, D.C.	Normal			X	
CYC					
Mayport	MSW/waste oil[j]	X	X		X
WS					
Alexandria	Normal			X	
Nicosia	Normal			X	
SD/FF					
Tsushima	Normal	X	X	X	
EGB					
Pittsfield	Experimental[k]				X

(continued)

TABLE 1-2. (continued)

Facility name	Test condition	Criteria pollutants	Acid gases	Metals	Organics
Starved air					
No controls					
Cattaraugus County	Normal				X
Dyersburg	Normal	X	X	X	X
N. Little Rock, 3/78	Normal	X			
N. Little Rock, 5/78	Normal	X			
N. Little Rock, 10/78	Normal	X		X	
Prince Edward Island	Normal	X	X	X	X
Prince Edward Island	Long[l]	X	X	X	X
Prince Edward Island	High[m]	X	X	X	X
Prince Edward Island	Low[n]	X	X	X	X
ESP					
Barron County	Normal	X	X	X	
Red Wing	Normal	X	X	X	X
Tuscaloosa	Normal	X		X	
RDF fired					
ESP					
Akron	Normal	X	X	X	X
Albany	Normal	X	X	X	X
Hamilton-Wentworth	F/None[o]	X			X
Hamilton-Wentworth	F/Low back[p]	X			X
Hamilton-Wentworth	F/Back[q]	X			X
Hamilton-Wentworth	F/Back, low front[r]	X			X
Hamilton-Wentworth	H/None[s]	X			X
Hamilton-Wentworth	H/Low back[t]	X			X
Niagara	Normal	X	X	X	
CYC/ESP					
Wright Pat. AFB	Normal				X
Wright Pat. AFB	Dense RDF[u]		X		
CYC/DI/ESP/FF					
Malmo	RDF[v]	X	X	X	

[a] Type of combustor design.

[b] Type of furnace.

[c] Emission control device(s) as follows: CYC = Cyclone; DI = dry sorbent injection; SD = spray dryer; EGB = electrostatic granular bed; ESP = electrostatic precipitator; FF = fabric filter; WS = wet scrubber; and WSH = water spray humidifier.

[d] Unit operated under normal conditions during tests.

[e] Unit operated at low combustion temperature during tests.

[f] Unit is designed to cofire sludge but burned only MSW during tests.

[g] Gases entering the fabric filter were at the temperature specified in °C.

[h] Normal operations: gases entering the fabric filter were at 140°C and normal lime feed rate was used.

[i] Sorbent recycle was used. Gases entering the fabric filter were at 140°C.

[j] Unit burned MSW and waste oil during tests.

[k] Tests were conducted at only two experimental conditions (polyvinyl chloride-free waste and low combustion chamber temperature) during these tests.

[l] Unit operated under longer feed cycle to decrease demand on the tractor operator during tests.

[m] Unit operated with high secondary chamber temperature during tests.

[n] Unit operated with low secondary chamber temperatures during tests.

[o] Unit operated under full load with no overfire air.

[p] Unit operated under full load with only lower back overfire air ports open.

[q] Unit operated under full load with both back overfire air ports open.

[r] Unit operated under full load with both back and lower front overfire air ports open.

[s] Unit operated under half load with no overfire air.

[t] Unit operated under half load with only lower back overfire air ports open.

[u] Unit burned densified RDF during tests.

[v] Unit burned RDF during tests.

TABLE 1-3. OVERVIEW OF SUPPLEMENTARY EMISSION DATA BASE

Facility name	Test condition	Metals	Organics
Mass burn			
Waterwall/ESP			
Avesto	Normal	X	
Iserlohn	Normal		X
MVA Lausanne	Normal	X	
MVA Munich	Normal	X	
Montreal (1982)	Normal		X
Montreal (1983)	Normal		X
Quebec (1981)	Normal		X
Umea (1984)	Normal		X
Umea (1985)	Normal		X
Zurich/Josephstrasse	Normal		X
Waterwall/DS/ESP			
Hamburg/Stapelfeld	Normal		X
MVA-I Borsigstrasse	Normal		X
MVA-II Stellinger M.	Normal		X
Waterwall/DS/ESP/FF			
Malmo	Normal		X
Waterwall/DS/FF			
Avg Borsigstrasse	Normal		X
Waterwall			
Issy-les-Moulineaux	Normal	X	
Saint-ouen	Normal	X	
Refractory/SPRAY/ESP			
Toronto I	Normal		X
Refractory/ESP			
Brasschaat	Normal		X
Harelbeke	Normal		X
Linkoping	Normal		X
Stuttgart	Normal		X
Zaanstad	Normal		X
Refractory			
Beveren	Normal		X
Milan I	Normal		X
Milan II	Normal		X
Starved air			
None			
Lake Cowichan	Normal		X
CS/ESP			
Schio	Normal[a]		X
Schio	Unprocessed		X
Fluid bed			
FF			
Eskjo	Normal		X

[a] Waste separated to produce compost is termed processed. This procedure is the normal operating condition for this facility.

2. Limitations concerning availability of key process and control device data. The data on combustion process and control system design and operation are often incomplete. Variations in combustor design, waste feed characteristics, and control device design and operation are expected to affect pollutant emission rates. The effects of missing data should be considered when emissions from different facilities are compared.

3. Limitations concerning nonstandardized test protocols. The relative quality of the reported data varies widely among sites. Major differences include variations in sampling and analysis methodology, levels of documentation of methods and results, and levels of quality assurance and quality control. Chapter 6 describes some of these variations. Any comparative analyses or general interpretation of MWC emissions or control system performance should be based on data from similar systems obtained by comparable methods of equivalent quality.

The remainder of this volume presents emission data and the supporting information needed to interpret those data. The overall results of the study are summarized in Chapter 2, which also includes a summary of the LREL's for different types of MWC's and limited analyses of the data. Chapter 3 contains brief descriptions of the 36 facilities for which documented test data were obtained and identifies the sampling and analysis methods used at those facilities to obtain emission data. No discussion is included for the 27 facilities for which test data were obtained but for which information on facility description and documentation of sampling and analysis methodology was lacking.

Because concerns about emissions of metals and organics have been raised, a number of additional emission tests are being planned. In Chapter 4, those planned emission tests are described, and projected schedules are tabulated. Descriptions of sampling and analysis methods used to gather the emission data are presented in Chapter 5. A tabular summary of the methods used to obtain this emission data base is presented to illustrate the variety of methods employed. Chapter 6 contains a description of the methodology used to compile the emission data base and to reduce that data base to its current format. Emission data for criteria pollutants, acid gases, metals, PCDD, PCDF, and other organic compounds are tabulated in Chapter 7. Data on process conditions, design specifications, and control device operating parameters also are presented. Supplement A is a list of available MWC emission test reports and related references. Supplement B is a summary of the symbols, acronyms, and abbreviations used throughout this volume. Supplement C contains the data log forms used to record the data extracted from the test reports for inclusion in the data base.

2. SUMMARY OF REPORTED EMISSIONS FROM MUNICIPAL WASTE COMBUSTORS

A data base has been developed on the emissions of criteria pollutants, acid gases, metals, and organics from MWC's. The objectives of this chapter are to summarize the overall emission ranges and LREL's for each pollutant by MWC type and to present results of limited analyses of the data base that focus on describing relationships among the test data. The chapter also identifies the facilities associated with each LREL, reports operating conditions and control techniques associated with the LREL's, and identifies sampling and analysis techniques associated with the LREL's. The identification of the LREL's in this chapter is in response to paragraph three, section (b), of the NRDC Settlement Agreement. This chapter also is intended to assist State and local agencies in future MWC permitting.

Relative to the objectives identified above, the LREL's reported in this chapter should be applied with caution. These LREL's typically reflect a specific facility operating under the conditions documented during a compliance test or a performance test designed to demonstrate the capability of the systems. The conditions achieved during these tests generally are not representative of the range of "normal" conditions but of "near-steady-state" conditions that are achieved by careful monitoring and control of the facility.

The discussion presented here identifies combustion and control approaches that led to low emissions. While LREL's may provide targets for new MWC's, the paucity of data precludes determination of the conditions under which any specific facility can achieve those levels. Furthermore, the LREL's for all pollutants have not been measured at the same facility, and combustor and control device design and operating conditions that provide optimal control for one pollutant may not provide optimal control for other pollutants. Consequently, a single facility may not reasonably be expected to achieve the LREL's presented for all pollutants.

The LREL's are reported in concentration units corrected to 12 percent CO_2 at dry standard conditions (20°C, 760 mm Hg). These units were selected for two reasons. First, concentrations are based only on stack gas measurements, whereas emission factors (mass emissions/mass feed) require both stack gas and feed measurements. Since mass feed measurements often were not well documented, they potentially increase the error in emission estimates. Second, on the average, waste feeds generally have stoichiometric air requirements that vary linearly with the heating value of the waste. Consequently, combustion gas flows normalized to a constant excess-air level (e.g., 12 percent CO_2) are expected to provide a consistent process measure based on heat input.

The LREL's are identified for criteria pollutants, acid gases, metals, and organics from data presented in Chapter 7. Tables 2-1 through 2-3 present summaries of the emission concentrations for these pollutants. Results are reported separately for mass-burn, excess-air facilities; modular, starved-air facilities; and RDF-fired facilities. The LREL's have not been distinguished by control device type. The LREL's are typically determined from data documented by emission reports consisting of a minimum of three test runs on a commercial-scale unit. If a lower value based on data from a pilot-scale study is available, it serves to complement the LREL from a commercial-scale facility. Data that are reported in the literature but have not been documented to date by test reports are included as supplementary information in Chapter 7.

The two sections below provide a more detailed assessment of the emission data. Section 2.1 identifies the LREL for each pollutant and discusses the facilities, equipment, and operating procedures associated with those levels. Section 2.2 presents the results of preliminary analyses of the test data. These analyses include evaluations of the bivariate relationships between PCDD/PCDF emissions and temperature and CO, assessment of the distributions of PCDD and PCDF among their homologs, assessment of the relative fraction of the laterally substituted isomers to the 2,3,7,8-TCDD toxic equivalent emissions, and assessment of the

TABLE 2-1. SUMMARY OF MWC CRITERIA POLLUTANT EMISSION RANGES[a]

	Range of pollutant emission concentrations[b]		
	Mass burn	Starved air	RDF fired
PM, mg/Nm^3 (gr/dscf)	5.49-1,530 (0.002-0.669)	22.9-303 (0.012-0.132)	220-533 (0.096-0.233)
SO_2, ppmdv	0.040-401	61-124	54.7-188
NO_x, ppmdv	39-376	255-309	263[c]
CO, ppmdv	18.5-1,350	3.24-67	217-430

[a] Results from commercial-scale facilities only.
[b] All concentrations are in units corrected to 12 percent CO_2.
[c] Data are available for only one test.

TABLE 2-2. SUMMARY OF MWC ACID GAS EMISSION RANGES[a]

	Range of pollutant emission concentrations[b]		
	Mass burn	Starved air	RDF fired
HCl, ppmdv	7.5-477	159-1,270	95.9-776
HF, ppmdv	0.620-7.21	1.10-15.6	2.12[c]
SO_3, ppmdv	3.96-44.5	d	d

[a] Results from commercial-scale facilities only.
[b] All concentrations are reported in units corrected to 12 percent CO_2.
[c] Data are available for only one test.
[e] No data are available.

TABLE 2-3. SUMMARY OF MWC METALS AND ORGANICS POLLUTANT EMISSION RANGES[a]

	Range of pollutant emission concentrations[b]		
	Mass burn	Starved air	RDF fired
As, $\mu g/Nm^3$	0.452-233	6.09-119	19.1-160
Be, $\mu g/Nm^3$	0.0005-0.327	0.0961-0.11	20.6[c]
Cd, $\mu g/Nm^3$	6.22-500	20.9-942	33.7-373
Cr, $\mu g/Nm^3$ [d]	21.3-1,020	3.57-394	493-6,660
Pb, $\mu g/Nm^3$	25.1-15,400	237-15,500	973-9,600
Hg, $\mu g/Nm^3$	8.69-2,210	130-705	170-441
Ni, $\mu g/Nm^3$	227-476	<1.92-553	128-3,590
2,3,7,8-TCDD, ng/Nm^3	0.018-62.5	<0.278-1.54	0.522-14.6
2,3,7,8-TCDF, ng/Nm^3	0.168-448	58.5[c]	2.69[c]
TCDD, ng/Nm^3	0.195-1,160	1.02-43.7	3.47-258
TCDF, ng/Nm^3	0.322-4,560	12.2-345	31.7-679
PCDD, ng/Nm^3	1.13-10,700	63.1-1,540	53.7-2,840
PCDF, ng/Nm^3	0.423-14,800	96.6-1,810	135-9,110

[a] Results from commercial-scale facilities only.

[b] All concentrations are reported in units corrected to 12 percent CO_2.

[c] Data are available for only one test.

[d] Total chromium emissions.

enrichment/depletion of metals in particulate matter across control devices.

2.1 LOWEST REPORTED EMISSION LEVELS

2.1.1 Criteria Pollutants

2.1.1.1 Particulate Matter. The LREL for PM from mass-burn, excess-air MWC's is 5.49 mg/Nm^3 (0.002 gr/dscf). This emission level was achieved at Unit 1 of the RESCO facility, Baltimore, Maryland, in 1985. The control device at Baltimore is a conventional wire/plate ESP with four fields. While the emissions at Baltimore are the lowest reported to date, the PM emissions from an MWC in Wurzburg, Germany, controlled by a dry scrubber/fabric filter (DS/FF) system were reported to be 9.15 mg/Nm^3 (0.0040 gr/dscf). These data are supplemented by data from other ESP- and DS/FF-controlled MWC's in the U.S., Japan, and Europe (Marion County, Oregon; Tulsa, Oklahoma; Tsushima, Japan; Malmo, Sweden; and Munich, Germany) that reported emission levels in the range of 11 to 30 mg/Nm^3 (0.005 to 0.013 gr/dscf).

The LREL for modular, starved-air MWC's is 22.9 mg/Nm^3 (0.012 gr/dscf) from Barron County, Wisconsin, an ESP-controlled facility. The Barron County data were measured during a compliance test conducted in July 1985. The facility consists of two Consumat incinerators. The secondary chamber temperature was maintained above 816°C (1500°F). The emissions are controlled by a two-chamber, two-stage ESP. The PM levels at Prince Edward Island, an MWC with no add-on control device, ranged from 7.5 to 11 times higher than those at Barron County.

Data from only five facilities are available on controlled emissions from RDF-fired facilities. The LREL of 220 mg/Nm^3 (0.096 gr/dscf), reported as an average of three test runs, was achieved at Niagara. This facility has two combustors each controlled by an ESP. An emission level of 89 mg/Nm^3 (0.039 gr/dscf) was achieved at the Hamilton-Wentworth facility in Ontario, Canada, during normal load, using only the lower overfire air port. This condition was observed for one test run only.

2.1.1.2 Sulfur Dioxide. The Tsushima, Japan, facility achieved the LREL for SO_2 emissions from a mass-burn incinerator on both an uncontrolled and a controlled basis. The SO_2 concentration upstream of the control system was 12.7 ppmdv corrected to 12 percent CO_2, and the controlled SO_2 concentration was 0.040 ppmdv. This reduction represents a control efficiency of greater than 99.7 percent. The Tsushima facility consists of two, mass-burn, refractory-wall units with no energy recovery system. Emissions from the incinerator are controlled by a Teller dry scrubbing system that includes an APC Quench Reactor, a dry venturi, and an FF. The APC Quench Reactor consists of a cyclone separator followed by the quench reactor where a two-fluid nozzle injects and atomizes the lime slurry upwards into the flue gas flow. The stoichiometric ratio of lime to the combination of HCl and SO_2 at the inlet ranged from approximately 6 to 10 during testing. The reverse-air FF operated at an inlet temperature of 230°C (440°F). The data reported for the composition of the waste feed at Tsushima indicate that the average sulfur content of the waste is 0.38 percent on a wet basis. This is within the range of sulfur content expected in municipal solid waste generated in North America. However, the uncontrolled SO_2 concentrations are about an order of magnitude less than those at any other tested facility, and the outlet concentrations are more than two orders of magnitude less than any other reported values, including those from other facilities using dry scrubbing.

The LREL of 41.5 ppmdv from a North American mass-burn unit was reported at Marion County. This new Martin-designed facility consists of two, mass-burn, waterwall combustor units. The air pollution control systems are identical for both of the units. The flue gases leave the boiler economizer and enter the bottom of the SD through a cyclonic inlet that removes large particles. Slaked pebble lime is used as a reagent; the lime is injected into the SD through an array of two-fluid nozzles. The stoichiometric ratio of lime to HCl is approximately 2.5. A dry venturi is located immediately before the FF inlet gas plenum. Tesisorb material is injected into the dry venturi. No temperature or excess-air data were presented in the test report.

The LREL of 61.0 ppmdv for modular MWC's was achieved at Prince Edward Island when the facility was operating under normal-load conditions. This concentration was about 20 to 30 percent less than the concentrations reported for the other operating conditions. An emission level of <29.3 ppm was reported at North Little Rock, Arkansas; however, data were not adequate to correct this value to a dry basis. Therefore, it cannot be compared to values achieved at Prince Edward Island.

Only three sets of test data are available for RDF-fired MWC's, and all tests were conducted at facilities that had only ESP's for control. Because ESP's provide virtually no SO_2 control, these data essentially represent uncontrolled emissions. The LREL of 54.7 ppmdv was achieved at the Hamilton-Wentworth, Canada, facility when it was operating under normal load with both back overfire air ports in operation. The Hamilton-Wentworth facility consists of two spreader-stoker boilers. Waste processing includes shredding and magnetic separation. No data on waste composition are available.

2.1.1.3 Oxides of Nitrogen. No test data have been collected from MWC's with pollution control equipment designed to reduce NO_x emissions. Furthermore, the process data that have been compiled are not adequate to assess the effects of combustion conditions on NO_x emissions. Consequently, all NO_x concentrations essentially represent uncontrolled emission levels. To the extent that data are available, combustion temperatures and excess-air levels associated with the LREL's are reported.

The LREL of 39 ppmdv for NO_x from mass-burn units was achieved at Unit 2 at McKay Bay, Florida. The McKay Bay facility has four refuse-fired boilers, each controlled with an ESP. The other units at McKay Bay had emission levels ranging from 100 to 106 ppmdv. The process data in the report were not adequate to explain the lower NO_x emission level for Unit 2. The facility at Braintree, Massachusetts, had the next lowest emission level of 153 ppmdv. The Braintree facility, which currently is not operating, has three identical combustors with Riley Stoker grates and boilers. The units operated with only underfire air and at a combustion zone temperature of about 630°C (1160°F). This temperature was the lowest combustion zone temperature reported for mass-burn facilities for which NO_x emissions were measured.

The LREL of 255 ppmdv for NO_x emissions from modular MWC units was achieved at Red Wing, Minnesota. The Red Wing MSW incinerator is a twin-unit facility manufactured by Consumat Systems. The emissions are controlled by a single ESP. The average secondary chamber temperature was 1003°C (1838°F). North Little Rock reported an emission level of 240 ppm, not corrected to dry conditions.

The only RDF-fired facility for which NO_x data are available is Albany, New York. The average NO_x concentration at Albany was 263 ppmdv during normal operation. The Albany facility is a single-chamber, waterwall unit with a traveling grate. The unit operated at approximately 120 percent excess air. No data are available on the average combustion zone temperature.

2.1.1.4 Carbon Monoxide. The combustor design and operating conditions associated with CO data compiled to date are not adequate to assess the effect of combustion controls on emissions. Consequently, all emission concentrations of CO are reported as uncontrolled. However, to the extent that data are available, combustion temperatures and excess-air levels associated with the LREL's are reported.

The LREL of 18.5 ppmdv for CO from mass-burn MWC's was achieved at the Marion County, Oregon, facility. This is a new facility of Martin design. The CO concentrations achieved at Marion County are about the same as those achieved at the facility with the second lowest concentration (Baltimore RESCO, Maryland, January 1985; 19.6 ppmdv).

The LREL of 3.24 ppmdv for CO from modular MWC's occurred at the Barron County, Wisconsin, facility. The CO concentrations were collected with Orsat apparatus and analyzed with an Horiba nondispersive infrared CO analyzer. The Red Wing facility reported a CO concentration of <2.11 ppmdv, but the test report authors questioned the measurement due to leakage problems. The CO levels achieved at Prince Edward Island were 10 to 20 times the LREL.

The LREL of 217 ppmdv for CO emissions from RDF-fired MWC's was achieved at the Malmo, Sweden, facility. The concentrations at other RDF-fired facilities were 1.6 to 7.3 times those at Malmo. The Malmo facility employs Martin reverse-reciprocating grates in the combustion chamber and Wagner-Biro two-stage boilers for heat transfer. The RDF processing includes a ballistic separator, a magnetic separator, and a shredder. During the RDF tests, the Malmo unit operated at a temperature of 820°C (1500°F) and about 60 percent excess air. During comparable operation burning unprocessed refuse at the Malmo facility, CO emissions were measured to be 158 ppmdv.

The lowest CO concentration achieved at a North American RDF facility was 346 ppmdv at Albany. This facility is a single-chamber, waterwall unit with a traveling grate. The unit operated at about 120 percent excess air. No data are available on combustion zone temperature.

2.1.2 Acid Gases

2.1.2.1 Hydrogen Chloride. The LREL of 7.50 ppmdv for HCl emissions from mass-burn MWC's was achieved at the Tsushima facility. The Tsushima facility is a Martin reverse-reciprocating grate, refractory furnace with an SD/FF emission control system. The stoichiometric ratio of lime to the combination of HCl and SO_2 at the inlet ranged from approximately 6 to 10 during testing. The LREL represents an HCl control efficiency of greater than 97 percent. A unit in Munich with an SD followed by an ESP had a higher HCl concentration (27.0 ppmdv) but achieved a comparable control efficiency (95 percent). The lowest emission level at a North American unit of 12 ppmdv was achieved at the Marion County facility. The lowest reported concentration from any facility (3.99 ppmdv) was achieved at Quebec. This concentration represents a 99.2 percent control efficiency achieved by a pilot scale DI/FF that operated on a slipstream from a full-scale MWC.

The LREL of 159 ppmdv for HCl emissions from modular MWC's with no control systems was achieved at the Dyersburg, Tennessee, facility. This level was about 25 percent of the lowest level reported at Prince Edward Island (627 ppmdv). No data are available on the chloride concentrations in the waste feed, but the unit is reported to fire 30 percent industrial waste and 70 percent municipal waste. For modular MWC's with an ESP, the LREL of 457 ppmdv was achieved at the Barron County, Wisconsin, facility. Barron County utilizes a two-chamber, two-stage ESP as its control device.

For RDF-fired facilities, the LREL of 95.9 ppmdv for HCl emissions was achieved at Wright Patterson Air Force Base (WPAFB), Dayton, Ohio. Because emissions are controlled only by an ESP, this concentration represents an uncontrolled emission level. No data are available on the chloride concentration in the waste feed to this system.

2.1.2.2 Hydrogen Fluoride. Data on HF emissions from MWC facilities are quite limited. For mass-burn units, the LREL of 0.620 ppmdv was achieved at Tsushima with an SD/FF control system. This concentration represents a 48 percent control efficiency. While the emissions from a unit using an O'Connor water-cooled rotary combustor with an ESP/WS at Kure, Japan, were higher (0.935 ppmdv) than those at Tsushima, the control system at Kure achieved a higher efficiency (68 percent). The WS at Kure is of a turbulent contacting adsorber design. No data are available on the composition of the scrubbing liquid. The lowest reported concentration for a North American facility (1.30 ppmdv) was achieved at Hampton in 1983. The Hampton facility is a single-chamber, waterwall unit with inclined reciprocating grates. An ESP is the only air pollution control device.

Tests for HF emissions were conducted on only two modular MWC's: Prince Edward Island, Canada, and Dyersburg, Tennessee. The LREL of 1.10 ppmdv was achieved at the Dyersburg unit.

Only one HF emission test was conducted on an RDF-fired facility. The LREL of 2.12 ppmdv was achieved at the Akron, Ohio, unit.

2.1.2.3 Sulfur Trioxide. The only SO_3 emission data that were identified are for mass-burn facilities. The LREL of 3.96 ppmdv was achieved with an ESP/WS control system at Kure, Japan. The control efficiency was 29 percent. Comparable emission levels were achieved at Tulsa (Unit 1, 10.1 ppmdv and Unit 2, 9.76 ppmdv).

2.1.3 Metals

Metals concentrations measured in MWC emissions are dependent on process parameters and emission test protocols. Process variables that are postulated to affect metals emissions include the concentration of metals in the waste feed, the specific physical and chemical composition of the metals in the feed, combustion zone temperatures, turbulence of the combustion bed, and air pollution control device performance characteristics. Emission test protocols vary widely for trace metal constituents both in terms of collection methods for particle- and gas-phase constituents and analytical techniques for constituent quantitation.

The paragraphs below identify LREL's for seven metals. These concentrations have been extracted from test data that were collected under a wide variety of operating conditions and with different test protocols. To the degree possible, the operating conditions and test methods associated with the LREL's are described. Frequently, though, data are not adequate to characterize operating conditions or test methods completely. The LREL's are reported from documented tests that consisted of a minimum of three separate test runs. The metals data from Wurzburg and Tsushima were based on a single run, and the results are somewhat uncertain because the particulate sample was quite small. Consequently, those data were not included as a part of the LREL determination.

2.1.3.1 Arsenic. For mass-burn MWC's, the LREL for As of 0.452 $\mu g/Nm^3$ was achieved at Munich with a Deutshe Babcock Anlagen (DBA) dry scrubber reactor followed by a DBA ESP. The DBA dry scrubber reactor consists of a cyclonic precipitator followed by a dual-fluid nozzle used for spraying the lime slurry into the flue gas stream. The sampling train consisted of EPA Method 5 (M5) on the front half and EPA Method 8 (M8) on the back half. Analysis was by atomic absorption spectrophotometry (AA), and the data represent both particle- and gas-phase emissions. Because no inlet measurements were reported, the efficiency could not be determined. The highest reported efficiency for As emissions from a mass-burn unit with a full-scale pollution control system was 99.4 percent, which was achieved by an ESP at Baltimore RESCO. The As emission concentration at Baltimore was 6.29 $\mu g/Nm^3$. The Baltimore data were collected by EPA Method 108 (M108), and the data represent both particle- and gas-phase emissions. The highest reported overall efficiency of greater than 99.98 percent was achieved during the low temperature (110°C) tests on a pilot-scale WSH/DI/FF at Quebec. The outlet concentration during these tests averaged 0.022 $\mu g/Nm^3$. The emissions were collected in an EPA M5 train modified to include aqua regia in the first two impingers; As concentrations were determined by formation of the metal hydride with analysis by flameless AA. These results include particle- and gas-phase As. The Quebec incinerator is of single-chamber, waterwall design with Von Roll grates.

For modular MWC's, the LREL for As of 6.09 $\mu g/Nm^3$ was achieved at normal operating temperatures with a standard operating cycle at Prince Edward Island. This level ranged from 45 to 65 percent of the concentrations reported for the other test conditions at Prince Edward Island. Concentrations measured at the outlet of an ESP at Barron County

(19.5 μg/Nm^3) were three times the lowest values reported at Prince Edward Island. Emissions at Barron County were collected by EPA M5, and As concentration in the M5 filters and probe washes was determined by AA. These results are particle-phase emissions only. Emissions at Prince Edward Island were collected in an EPA M5 train that was modified by using aqua regia in the first two impingers and potassium permanganate ($KMnO_4$) in the third impinger. Concentrations were determined by direct current plasma emission spectrometry (DCPES). These results include both particle- and gas-phase emissions.

For RDF-fired incinerators, the LREL for As of 19.1 μg/Nm^3 was achieved at Albany. The RDF processing included air and magnetic separation and shredding. The incinerator is a single-chamber, waterwall unit with a traveling grate stoker. It has a three-field ESP for particulate control. Arsenic emissions were measured using EPA M108, which captures both gas- and particle-phase emissions.

2.1.3.2 Beryllium For mass-burn MWC's, the LREL of 0.0005 μg/Nm^3 for Be was achieved at the Munich facility. This facility is controlled by a DBA SD reactor followed by an ESP. Because no inlet data were reported, the control efficiency is not known. Tests were conducted using a multiclone sampling system with analysis by AA. Consequently, the data represent only particle-phase emissions. The LREL for a North American facility was 0.003 μg/Nm^3 achieved at the ESP outlet at Tulsa. The Tulsa emissions were measured using EPA Method 104 (M104) and represent both gas- and particle-phase emissions.

The LREL for Be emissions from modular MWC's was achieved at Red Wing, Minnesota. At Red Wing, the average uncontrolled Be emission concentration was 0.0961 μg/Nm^3. The sample at Red Wing was collected in an EPA M5 train and analyzed by inductively coupled argon plasma spectrophotometry (ICAPS). The concentration reported at Dyersburg was 0.11 μg/Nm^3.

The LREL from RDF-fired MWC's was achieved at Albany. The average concentration at the Albany facility was 20.6 μg/Nm^3. The data at Albany were obtained by EPA M104 and represent both particle- and gas-phase emssions.

2.1.3.3 Cadmium. For mass-burn MWC's, the LREL for Cd emissions of 6.22 μg/Nm^3 was achieved at Malmo. This concentration represents a control efficiency of over 99 percent. Facility components at Malmo include Martin reverse-reciprocating grates, Wagner-Biro two-stage boilers, and a control system that includes a DI followed by an ESP and an FF. Sampling was conducted using an EPA M5 train that was modified to include nitric acid (HNO_3) in the first two impingers. Analysis was by AA. This system measures both gas- and particle-phase cadmium. Another facility with a relatively low concentration is Munich (8.57 μg/Nm^3). This concentration represents particle-phase emissions only. An emission level of 0.482 μg/Nm^3 was achieved during the 125°C tests on the pilot-scale WSH/DI/FF at Quebec. This emission level represents a control efficiency of greater than 99.96 percent. The emissions at Quebec were measured using an EPA M5 train that was modified to include aqua regia in the impingers. The system captures both gas- and particle-phase emissions. Analysis was by DCPES.

For modular MWC's, the LREL of 20.9 μg/Nm^3 for Cd was achieved at Barron County, Wisconsin. The Barron County facility consists of two, Consumat model #CS-1600 combustors, both controlled by a single ESP. Emissions were collected by EPA M5, and Cd concentration in the M5 filters and probe washes was determined by AA. These results are particle-phase emissions only. The next lowest emission level reported for a modular unit was 238 μg/Nm^3 achieved at Dyersburg. The combustor at Dyersburg is a Consumat unit with no add-on pollution control equipment. The emissions were collected in an EPA M5 train (particle phase only) and analyzed by X-ray fluorescence (XRF).

The LREL of 33.7 μg/Nm^3 for Cd emissions from RDF-fired MWC's was obtained at the Albany incinerator described in the As discussion (Section 2.1.3.1). The emissions were collected in an EPA M5 train that was modified to include HNO_3 in the first two impingers; analysis was by AA. Consequently, these data represent both gas- and particle-phase emissions.

2.1.3.4 Chromium. For mass-burn MWC's, the LREL for total Cr emissions of 21.3 μg/Nm^3 was achieved at the Baltimore RESCO facility using a multiclone sampling system with analysis by AA. The Baltimore facility is of Von Roll design with an ESP for PM control. The highest reported control efficiency for Cr emissions from full-scale systems was 99.0 percent at Baltimore. This result includes only particle-phase emissions. A lower emission level of 0.229 was achieved at the Quebec pilot-scale SD/FF during the 140°C test with no recycle. This emission level represents a control efficiency of greater than 99.97 percent. (The concentration of 0.483 µg/Nm^3 achieved during the 110°C test on the WSH/DI/FF at Quebec represents a control efficiency of greater than 99.98 percent.) The samples were collected in an EPA M5 train modified to include aqua regia in the impingers to collect gas- and particle-phase emissions. Analysis was by DCPES.

The LREL of 3.57 µg/Nm^3 for total Cr emissions from modular MWC's was achieved at Barron County. The Barron County facility consists of two, identical Consumat units in parallel connected to a single ESP. Sampling was conducted with an EPA M5 train, and Cr concentration in the M5 filters and probe washes was determined by AA. Consequently, these data represent only particle-phase chromium.

For RDF-fired facilities, the LREL of 493 µg/Nm^3 for total Cr was achieved at the Akron incinerator. This concentration was less than 10 percent of that reported for Albany (6,600 µg/Nm^3). The Akron combustor is a semisuspension stoker-grate facility. Particulate matter is controlled by an ESP. The RDF processing includes shredding, air classification, and magnetic separation. The samples were collected in the cyclone/filter sections of a source assessment sampling system (SASS) train. Analysis was by XRF. This method captures only particle-phase chromium emissions. The emissions measured at Albany were both particle and gas phase.

2.1.3.5 Lead. For mass-burn MWC's, the LREL for Pb of 25.1 µg/Nm^3 was achieved at the Marion County facility, which consists of two, mass-burn, waterwall combustor units. Emissions were collected using EPA M12. Each combustor is controlled by an SD with a dry venturi followed by a reverse-air FF. An emission level of 1.23 µg/Nm^3 was achieved at the 140°C tests on the pilot-scale SD/FF at Quebec. This concentration represents a control efficiency of greater than 99.99 percent. Concentrations during the other tests at Quebec range from

2.89 to 6.53 μg/Nm^3. Emissions were collected in an EPA M5 train modified to include aqua regia in the impingers and analyzed by DCPES to determine both gas- and particle-phase emissions. The highest reported control efficiency was achieved at Malmo (99.1 percent). The reported concentration associated with this efficiency was 131 μg/Nm^3. The Malmo tests measured both particle- and gas-phase emissions.

The LREL of 237 μg/Nm^3 for Pb emissions from modular MWC's was measured at the ESP outlet at Barron County. Samples were collected in the front half of an EPA M5 train. Analysis was by AA. These results are particle-phase emissions only. Emissions at Dyersburg and Prince Edward Island were about 60 times higher than those at Barron County.

The Albany MWC achieved the LREL of 973 μg/Nm^3 for Pb emissions from an RDF-fired MWC. Both particle- and gas-phase samples were collected in an EPA M5 train that was modified to include HNO_3 in the first two impingers and were analyzed by AA. The Pb emissions at Albany were lower than those at Akron by a factor of about 10.

2.1.3.6 Mercury. Data on Hg emissions from mass-burn MWC's are more limited than data on other metal species except Be. The LREL of 8.69 μg/Nm^3 was measured at Kure at the inlet location of the control device using a unidentified method. The next lowest emission level of 10.4 μg/Nm^3 was achieved during the 140°C tests of the pilot-scale SD/FF at Quebec. This concentration represents a control efficiency of 94.6 percent. The highest efficiency achieved at Quebec was 97.4 percent (at an outlet concentration of 13.7 μg/Nm^3) during the 125°C WSH/DI/FF tests. Greater than 90 percent control was achieved at all test conditions at Quebec except the 200°C WSH/DI/FF tests. During the 200°C tests, higher concentrations were measured at the outlet than at the inlet. Emissions were collected at Quebec using an EPA M5 train modified to include $KMnO_4$ in the impingers. Analysis was by AA. Other reported concentrations include 40.0 μg/Nm^3 at Braintree and 187 μg/Nm^3 at Malmo. For all facilities, samples were collected in impinger solutions with analysis by AA except for the unidentified method used at Kure.

For modular MWC's, the LREL of 130 μg/Nm^3 for Hg was achieved at Dyersburg. The concentrations reported for Prince Edward Island were 4.4 to 8.5 times those reported at Dyersburg. The sample at Dyersburg was collected in SASS train impingers containing HNO_3 and $KMnO_4$ and was analyzed by AA.

For RDF-fired MWC's, the LREL of 170 $\mu g/Nm^3$ for Hg was achieved at the inlet to the control device at Malmo. The samples were collected in an impinger train containing HNO_3 and $KMnO_4$ and were analyzed by AA. Comparable emission concentrations (184 $\mu g/Nm^3$) were achieved at the ESP outlet at the Akron facility. The samples were collected in SASS train impinger solutions comparable to those used at Malmo.

2.1.3.7 Nickel. Data are quite limited on Ni emissions from mass-burn MWC's. The LREL of 227 $\mu g/Nm^3$ was achieved at Hampton in 1982. The Hampton facility consists of two, mass-fired, waterwall incinerator-boilers. The facility is equipped with an ESP. Emissions were obtained in the front half of a SASS train with analysis by XRF and represent particle-phase only. The lowest reported level for Quebec of 0.480 $\mu g/Nm^3$ was achieved during the 125°C WSH/DI/FF test. This concentration represents a control efficiency of greater than 99.97 percent. The data from Quebec include both gas- and particle-phase emissions.

The LREL of <1.92 $\mu g/Nm^3$, which is below the detection limit, for Ni emissions from modular MWC's was achieved at Red Wing, Minnesota. The Red Wing facility is a Consumat unit with an ESP. Sampling was done with an EPA M5 sampling train. Analysis was by ICAPS. The results include both gas- and particle-phase emissions. The level reported at Dyersburg was about 40 times the level measured at Red Wing. The samples at Dyersburg were collected in an EPA M5 train (front half only) and were analyzed by XRF. Consequently, the data represent only particle-phase emissions.

For RDF-fired MWC's, the LREL for Ni of 128 $\mu g/Nm^3$ was achieved at Akron at the outlet of the ESP. This concentration was a factor of 28 below the concentration reported for Albany. The sample was collected in an EPA M5 train (front half only) and was analyzed by XRF.

2.1.4 Organics

Table 2-3 presents ranges of emissions for 2,3,7,8-TCDD; 2,3,7,8-TCDF; TCDD; TCDF; and the summation of the tetra- through octa-homolog groups. To date, only limited data have been collected on control device efficiencies for PCDD and PCDF, so only outlet concentrations are reported for most tests. Generally, for each class of MWC, the same facility or the same vendor design had the LREL for each of the four pollutant classes. For commercial-scale, mass-burn units, Marion County had the LREL's for five of the six PCDD/PCDF categories identified above. The Wurzburg facility, another Martin-design MWC, had the LREL for 2,3,7,8-TCDD. For modular MWC's, the LREL was achieved at Prince Edward Island operating under high secondary combustion temperatures for four of the six categories. Red Wing achieved the LREL for 2,3,7,8-TCDD and 2,3,7,8-TCDF. For RDF-fired facilities, the LREL's for TCDD, TCDF, PCDD, and PCDF were achieved at WPAFB. Albany achieved the LREL for 2,3,7,8-TCDD and 2,3,7,8-TCDF. Added data on PCDD/PCDF control efficiencies are expected in the near future from MWC facilities in Massachusetts and New York. The paragraphs below briefly describe these facilities, identify the organic test methods used at these facilities, and present the LREL's.

The Marion County and Wurzburg facilities are new incinerators of Martin design with reverse-reciprocating grates. Emissions are controlled by an SD/FF at Marion County and a WSH/DI/FF at Wurzburg. The PCDD and PCDF emissions at both units were collected in an EPA modified Method 5 (MM5) train as specified by the American Society of Mechanical Engineers (ASME) draft PCDD/PCDF protocol.[1] The LREL's achieved at Marion County are 0.168 for 2,3,7,8-TCDF, 0.195 for TCDD, 0.322 for TCDF, 1.13 for PCDD, and 0.423 for PCDF, all expressed in units of ng/Nm^3. The LREL of 0.018 ng/Nm^3 for 2,3,7,8-TCDD was achieved at Wurzburg. Similar levels for PCDD and PCDF emissions were achieved during WSH/DI/FF and SD/FF tests at Quebec. Quebec reports a control efficiency of greater than 99.9 percent for PCDD and PCDF emissions. The combustor at Quebec was a single-chamber, waterwall unit with Von Roll grates. The control device was a pilot-scale Flakt system that operated on a slipstream from the combustor. The Quebec tests also were conducted using the draft ASME protocol. The Wurzburg facility with an SD/FF achieved emission levels of 22.1 ng/Nm^3 for PCDD and 27.8 ng/Nm^3 for PCDF. No control efficiency data are available for either Wurzburg or Marion County.

The Prince Edward Island facility consists of two-chamber Consumat combustion systems with no add-on pollution control systems. During the high secondary temperature tests, the facility operated with a primary combustion chamber temperature of 700°C (1300°F) and a secondary combustion chamber temperature of 1080°C (1970°F). The average CO concentration during those tests was 33 ppmdv, and the excess-air level was about 80 percent. The tests were conducted using the MM5 train as specified by the ASME draft PCDD protocol. The LREL's are 1.02 ng/Nm^3 for TCDD, 12.2 ng/Nm^3 for TCDF, 63.1 ng/Nm^3 for PCDD, and 96.6 ng/Nm^3 for PCDF. The emission measurements for PCDD/PCDF were collected in the cyclone, filter, and XAD-2 resin catch of an MM5 train and analyzed by high resolution gas chromatography/mass spectroscopy (HRGC/MS). The LREL's for 2,3,7,8-TCDD (<0.297 ng/Nm^3) and 2,3,7,8-TCDF (68.9 ng/Nm^3) were achieved at Red Wing, Minnesota. Red Wing consists of two Consumat incinerators, both controlled by a single ESP. The MM5 train was used to measure PCDD and PCDF. Analysis was by gas chromatography/mass spectroscopy (GC/MS).

The WPAFB facility is a spreader-stoker waterwall boiler. Particulate emissions are controlled by a CYC/ESP system. No operating data are available for the facility. Sampling was conducted with an EPA MM5 train with XAD-2 resin cartridge between the second and third impingers. Organic extraction was by toluene and methane with analysis by GC/MS. The LREL's are 3.47 ng/Nm^3 for TCDD, 31.7 ng/Nm^3 for TCDF, 53.7 ng/Nm^3 for PCDD, and 135 ng/Nm^3 for PCDF. The Albany incinerator is a single-chamber, waterwall unit with a traveling-grate stoker. Particle-phase emissions are controlled by a three-field ESP. No data are available on operating conditions during the test. Sampling and analysis were conducted by the ASME draft protocol. The LREL's for 2,3,7,8-TCDD and 2,3,7,8-TCDF are 0.522 ng/Nm^3 and 2.69 ng/Nm^3, respectively.

2.1.5 Supplementary Emission Data

Supplementary data on PCDD, PCDF, and metals emissions are available for 24 facilities and referenced as items 31 through 34 and 37 in Appendix A. These data are presented in Tables 7-56 through 7-58. Because no documentation of incinerator operations or test methodologies has been obtained, these data are considered to be less reliable than the data reported above. Given these constraints, the LREL's for PCDD and PCDF based on the supplementary data are 0.001 ng/Nm^3 for TCDD, 0.002 ng/Nm^3 for TCDF, 0.013 ng/Nm^3 for PCDD, and 0.020 ng/Nm^3 for PCDF.

All of these emission levels were obtained from 1982 tests at a Montreal, Canada, mass-burn facility with an ESP for particulate control. The author(s) in Reference 2 consider the Montreal results to be estimates because (1) the PCDD results are quite low compared to the other incinerators, (2) they were unable to draw conclusions to explain the variations and low levels in the results, and (3) the test method was still under development and has since been improved.[2]

Other facilities also reported emission levels lower than the LREL's obtained from the documented test reports. Facilities that reported TCDD concentrations of less than 1.6 ng/Nm^3 are Malmo (0.15 ng/Nm^3), Iserlohn (1.03 ng/Nm^3), Linkoping (0.45 ng/Nm^3), and Milan II (0.1 ng/Nm^3). No data are available on CO_2 concentrations for these facilities so the results have not been corrected to 12 percent CO_2. Consequently, the results are likely to be biased low relative to the documented data.

Data are quite limited on concentrations of homologs other than TCDD. No supplementary data other than those at Montreal had PCDD emissions less than the 18.9 ng/Nm^3 reported at Tulsa. The lowest concentration reported other than Montreal was 48.1 ng/Nm^3 at Quebec in 1981.

Other than Montreal, three facilities--Malmo (2 ng/Nm^3), Schio (6.6 ng/Nm^3), and Linkoping (0.6 ng/Nm^3)--reported TCDF emission concentrations less than the 6.9 ng/Nm^3 reported at Wurzburg. Again, these values may be biased low as they have not been corrected to 12 percent CO_2. Except for Montreal, none of the concentrations of PCDF reported in the supplementary data are lower than the 19.0 ng/Nm^3 reported at Tulsa. The lowest reported value of 97 ng/Nm^3 (not corrected) was achieved at Zurich/Josephstrasse.

Although the facility at Schio (Vicenza, Italy) did not achieve the LREL's for TCDD and TCDF emissions, the test data do supply control efficiencies for the alkaline water shower/ESP.[3] The tests at Schio were conducted using processed and unprocessed waste. The TCDD concentrations of 8.9 ng/Nm^3 for processed waste and 1.8 ng/Nm^3 for unprocessed wastes represented control efficiencies of 61.7 and 90.6 percent, respectively. Similarly, the TCDF concentrations of 23.7 ng/Nm^3 for processed waste and 6.6 ng/Nm^3 for unprocessed waste represented control efficiencies of 82.6 and 82.4 percent, respectively.

2.2 PRELIMINARY ANALYSES OF EMISSION DATA

Although the primary objectives of this study are to collect data on MWC emissions and to compile those data in a format that will allow comparison of the data from different tests, some preliminary analyses of the data also were conducted. These preliminary analyses focus on describing relationships among the test data rather than on developing analytical or empirical models to explain emissions or emission control.

The analyses focus on two pollutant groups--PCDD/PCDF and metals--and are directed toward two objectives. The first is to develop a better understanding of PCDD and PCDF emissions, particularly with respect to the relationship of mass emissions to 2,3,7,8-TCDD toxic equivalents and to the distribution of PCDD and PCDF emissions among specific homologs and isomers. The second objective is to describe the performance of control devices for specific metals relative to the performance of those control devices for particulate matter.

The nature of the data presented in this volume limits the analyses that can be performed and the confidence that can be placed in the results that were obtained. The test reports that contained the data presented herein were reviewed in detail, and all the data presented were deemed to be valid and of acceptable quality. However, the characteristics of the combustion process and the developmental nature of the sampling and analysis procedures result in trace pollutant emission measurements and associated process measurements that are difficult to compare and analyze parametrically. Earlier studies of MWC emissions also have noted the problems of comparing data from different tests.[4-6] The four major sources of uncertainty discussed below have a confounding influence on the analyses of MWC emission data.

First, because no reference test method is available for PCDD and PCDF and because reference methods are available for only some metals, the test methods used to collect the data varied from site-to-site. For metals, the major differences are the sample collection medium and the analytical technique. Although all methods used show good precision, data are not adequate to assess the relative accuracy of the methods. Consequently, the results from different tests may not be comparable. For PCDD and PCDF measurements, the major differences in the methods are the use of different solvents for extraction, subjection of the extracts to different cleanup techniques, the use of varied spiking techniques to determine PCDD/PCDF recovery efficiencies, and implementation of different data reduction methods to account for these recovery efficiencies in calculating final results. Because no international consensus has been reached on preferred techniques, no corrections to the data were made to account for differences in the methods. The values included in this report are those presented in the original references. The variability in the data introduced by the different methods results in some uncertainty in the results from the data analyses.

Second, for test results that were obtained with the same test methods, the inherent imprecision of the analytical methods introduces uncertainty into the data analysis. The analytical methods used for PCDD and PCDF quantitation generally produce results that have a precision of ±30 percent (as measured by relative standard deviation) for relatively clean samples. In some cases, the methods are less precise. This imprecision makes it difficult to establish parametric relationships between PCDD and PCDF emissions and other combustion variables.

Third, both metals and PCDD and PCDF are trace contaminants in the stack gas stream. As such, their generation is expected to exhibit significant spatial and temporal variability within the incinerator. However, the measurement methods that are available produce long-term average emission rates, and process monitoring techniques typically do not define the microscale variations throughout the facility. Because these methods mask the variability of the emissions, the dependence of emissions on short-term changes in the process is difficult to assess.

Finally, both metals and organics emissions are influenced by a large number of waste feed and process operating characteristics. Factors that have been hypothesized as influencing PCDD/PCDF emission characteristics include waste feed characteristics such as chlorine content, moisture content, lignin content, and specific metals content and operating parameters such as temperatures (primary, secondary, grate, boiler, control device), localized oxygen (O_2) and moisture concentrations, fly ash carbon and metals content, concentration of HCl in the stack gas, and residence time of particle- and gas-phase pollutants in different segments of the process. Because the number of data points is still limited and because, for most tests, many of these variables either were not measured or were obtained with monitors that were not rigorously calibrated, the data base is not adequate to establish parametric relationships between trace contaminant emissions and process operating conditions.

The results of the analyses presented in the subsections below should be interpreted in light of the uncertainties described above. Those subsections present descriptive statistics of the trace contaminant emissions and some preliminary results from bivariate analytical techniques. Given these limited analyses, the results are considered to be indicators of potential areas of further study. They should not be used to establish definitive conclusions regarding trace contaminant emissions.

2.2.1 PCDD/PCDF Analyses

Analyses of the PCDD/PCDF data were conducted to describe the variation in the PCDD/PCDF emissions and to provide a preliminary assessment of some of the factors that might relate to those variations. The analyses focused on three areas. First, estimates of PCDD/PCDF emissions in units of 2,3,7,8-TCDD toxic equivalents were developed, and these toxic equivalent measures were compared to mass emission measures. Second, PCDD/PCDF emission rates (expressed as stack gas concentration of total PCDD/PCDF) were compared to key process or stack gas parameters. Finally, the distributions of PCDD and PCDF among the different homolog or isomer groups were examined.

Estimates of PCDD/PCDF emissions as measured by 2,3,7,8-TCDD toxic equivalents were calculated using the methods described by Mukerjee and Cleverly.[7] Calculations were performed on both a homolog-specific and an isomer-specific basis. The results are shown in Table 2-4.

Linear regression analyses were used to compare the 2,3,7,8-TCDD toxic equivalents (homolog based) to PCDD/PCDF concentrations and to TCDD concentrations. Separate analyses were performed for each type of MWC. The results of the analysis indicated that the toxic equivalents are closely related to both TCDD (correlation coefficients ranged from 0.972 to 0.997) and PCDD/PCDF (correlation coefficients ranged from 0.927 to 0.998). These results indicate that mass emission measures based on

TABLE 2-4. SUMMARY OF PCDD AND PCDF EMISSIONS FROM MWC's

		Emissions, ng/Nm^3 at 12 percent CO_2[a]			
				2,3,7,8-TCDD toxic equivalents	
Facility	Test condition[b]	PCDD/PCDF	TCDD	Homolog based	Isomer based
Chicago NW[c]	Normal	258	8.39	22.1	
Hampton (1981)	Normal	16,800	800	2,040	
Hampton (1983)	Normal	9,630	214	1,480	
Hampton (1984)	Normal	25,500	1,160	3,490	
Tulsa	Normal	34.4	1.61	4.40	0.75
North Andover	Normal	335	8.38	24.9	4.7
Saugus	Normal	580	31.9	80.5	6.8
Umea (fall)	Normal	501	51.6	107	7.2
	Low temperature	745	64.8	141	7.3
Umea (spring)	Normal	492	<12	52.1	3.8
Marion County	Normal	1.55	0.195	0.263	0.11
Quebec (SD)[d]	110	2.65	BD	0.00508	
	125	BD	BD	BD	
	140	1.03	BD	0.00103	
	200	8.04	BD	0.124	
Quebec (DI)	140	BD	BD	BD	
	140 & R	1.33	0.0639	0.0995	
Wurzburg	Normal	50.0	1.91	5.26	0.39
Philadelphia (NW1)	Normal	11,300	378	1,280	140
Philadelphia (NW2)	Normal	5,760	365	1,110	101
Cattaraugus[e]	Normal	258	8.1	31.7	
Redwing	Normal	3,310	43.7	284	34
Prince Edward Island	Normal	253	3.05	16.0	
	Long	268	5.09	21.0	
	High	160	1.02	8.91	
	Low	224	3.05	11.6	
Albany	Normal	578	19.9	118	
Hamilton-Wentworth	F/None	9,230	590	1,480	
	F/Low back	10,900	560	1,540	
	F/Back	12,000	570	1,660	
	F/Back, low front	21,500	3,500	5,960	
	H/None	14,100	1,200	2,640	
	H/Low back	11,500	700	1,760	
Wright Patterson	Normal	189	3.47	8.47	

[a] BD = Below detection limit.
[b] Test conditions defined in Section 7.
[c] No PeCDD or PeCDF measured. Values for PCDD/PCDF and 2,3,7,8-TCDD toxic equivalents biased low.
[d] Values below detection limit assumed to be zero for toxic equivalents calculations.
[e] Values not corrected to 12 percent CO_2.

either TCDD concentration or PCDD/PCDF concentration can be used as surrogates for toxic equivalency measures in analyses of PCDD and PCDF emissions.

The contribution of specific isomers to the 2,3,7,8-TCDD toxic equivalent measure based on isomer-specific calculations also were examined. The results are tabulated in part in Table 2-5. These data indicate that the laterally substituted tetra and penta isomers of PCDD and PCDF account for 70 to 98 percent of the 2,3,7,8-TCDD toxic equivalent emissions. The high level of contribution from these isomers is not surprising considering the heavy weight they received in the toxic equivalency method. The data from these tests were reviewed for possible factors that might account for the variation in the contribution of the specific isomers, but no apparent trends related to combustor parameters or control techniques were identified.

Since total PCDD/PCDF concentrations were demonstrated to be a reasonable surrogate for 2,3,7,8-TCDD toxic equivalent emissions, the available data on total PCDD/PCDF concentrations were evaluated to assess relationships between PCDD and PCDF emissions and process or stack gas parameters. Factors that have been postulated by researchers as being related to PCDD and PCDF emissions are stack gas CO concentration, stack gas PM concentration, combustion gas moisture content, excess air (as measured by stack gas O_2 concentration), air distribution, temperatures at different locations in the system, and waste feed characteristics (e.g., heating value, chloride content, moisture content, plastics fraction). The information in the data base was not sufficient to assess the relationship of emissions to combustion gas moisture content, air distribution, or waste characteristics. Preliminary analyses were conducted for the other variables.

The relationships of PCDD and PCDF emissions to stack gas CO, O_2, and PM concentrations were examined by using linear regression and rank order correlation techniques. Linear regression analysis measures the strength of the linear interdependence of the variables of interest while rank order correlation analysis is a nonparametric measure of the strength of the monotonic relationship between the variables of interest. Separate analyses were conducted for each of the three types of MWC's.

TABLE 2-5. SUMMARY OF 2,3,7,8-TCDD TOXIC EQUIVALENT CONTRIBUTION FOR 2,3,7,8-TETRA AND -PENTA ISOMERS

Laterally substituted congener	Fraction of the 2,3,7,8 TCDD toxic equivalent emissions contributed by specific isomer class							
							Philadelphia	
	Peekskill	Oneida	Occidental	Marion County	Wurzburg	Tulsa	NW1	NW2
TCDD	0.17	0.015	0.15	0.75	0.06	0.14	0.10	0.14
PeCDD	0.23	0.16	0.39	0.042	0.35	0.14	0.30	0.41
TCDF	0.13	0.062	0.041	0.16	0.089	0.42	0.043	0.037
PeCDF	0.39	0.46	0.23	0.023	0.22	0.20	0.29	0.21
Total	0.92	0.70	0.81	0.98	0.72	0.90	0.73	0.80

The results of the analyses showed no significant relationship between either O_2 or PM and PCDD and PCDF emissions. Further, the correlation coefficients for the three MWC types for CO and PCDD/PCDF concentrations were not statistically significant. However, the results of the rank order correlation analyses showed a significant relationship between CO and PCDD/PCDF concentrations for mass-burn MWC's and the combined group of MWC's. The results shown in Table 2-6 indicate that CO concentrations and PCDD/PCDF concentrations are positively related. The relationship is shown graphically in Figure 2-1. The graph and the statistical analyses indicate that in general, high PCDD/PCDF concentrations are associated with high CO concentrations and low PCDD/PCDF concentrations are associated with low CO concentrations. However, the data are not adequate to establish a functional relationship between the variables.

The role of combustor system temperature on the formation and destruction of PCDD and PCDF has been the subject of extensive research. Dellinger reported that, in a laboratory setting, PCDD, PCDF, and most precursors are decomposed in the presence of O_2 at temperatures above approximately 850°C.[8] Consequently, most trace organic contaminants should be destroyed if high temperatures are achieved in the combustion zone. However, recent studies by Vogg and Hagenmaier indicate that PCDD and PCDF can form on fly ash at temperatures in the range of 250°C to 350°C.[6,9] These results suggest that PCDD and PCDF could form in lower temperature regions of the MWC system downstream from the combustion chamber.

In light of these findings, temperature measures are needed from different components of the MWC system (grate, primary chamber, secondary chamber, boiler inlet and outlet, and control device inlet and outlet) to assess the relationship of PCDD and PCDF emissions to temperature. A review of the data base indicated that temperature measurements were not sufficiently comparable to allow analysis of the temperature and PCDD/PCDF relationships among most sites. However, the data from multiple conditions at two sites, Prince Edward Island and Hamilton-Wentworth, were sufficient to allow preliminary analyses.

TABLE 2-6. RANK ORDER CORRELATION RESULTS FOR CO vs. PCDD/PCDF

Incinerator type	No. of tests	r_s
Mass burn	14	0.52[a]
Modular	5	0.040
RDF fired	7	0.07
Total	25	0.69[b]

r_s = Spearman's rank order correlation coefficient.

[a] A positive relationship is indicated at the 0.05 level of significance.

[b] A positive relationship is indicated at the 0.001 level of significance.

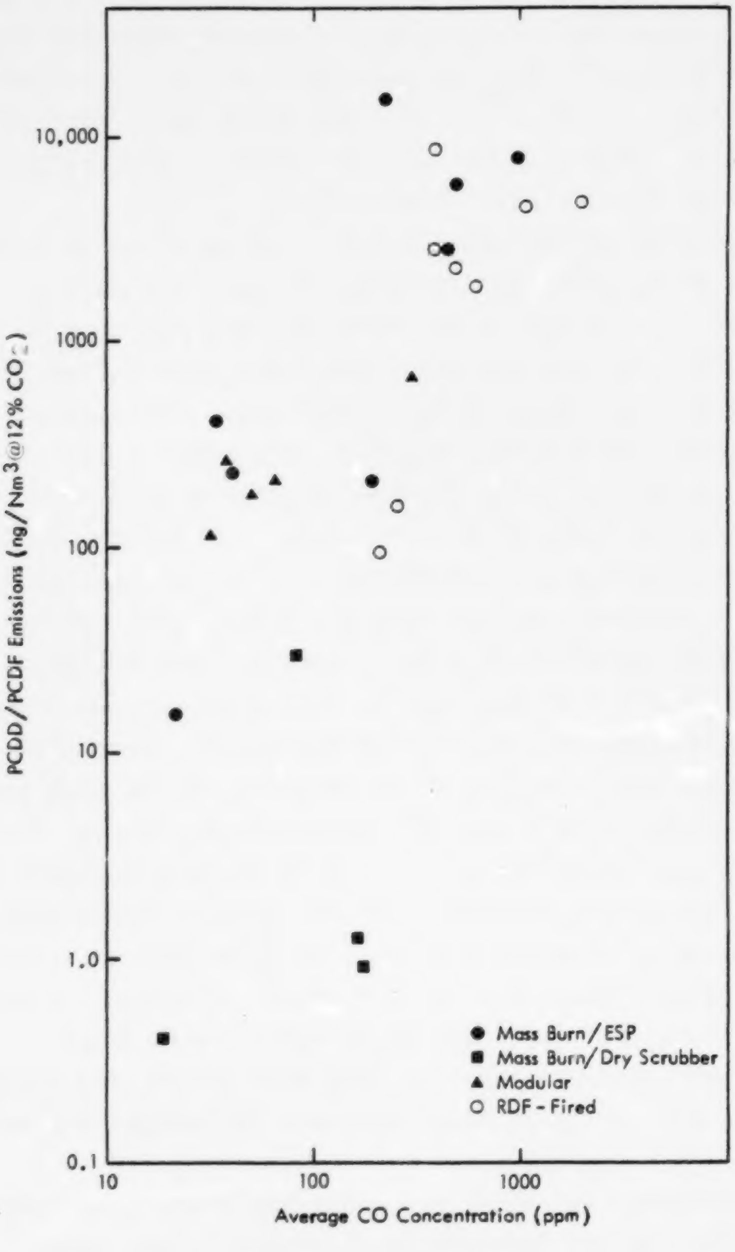


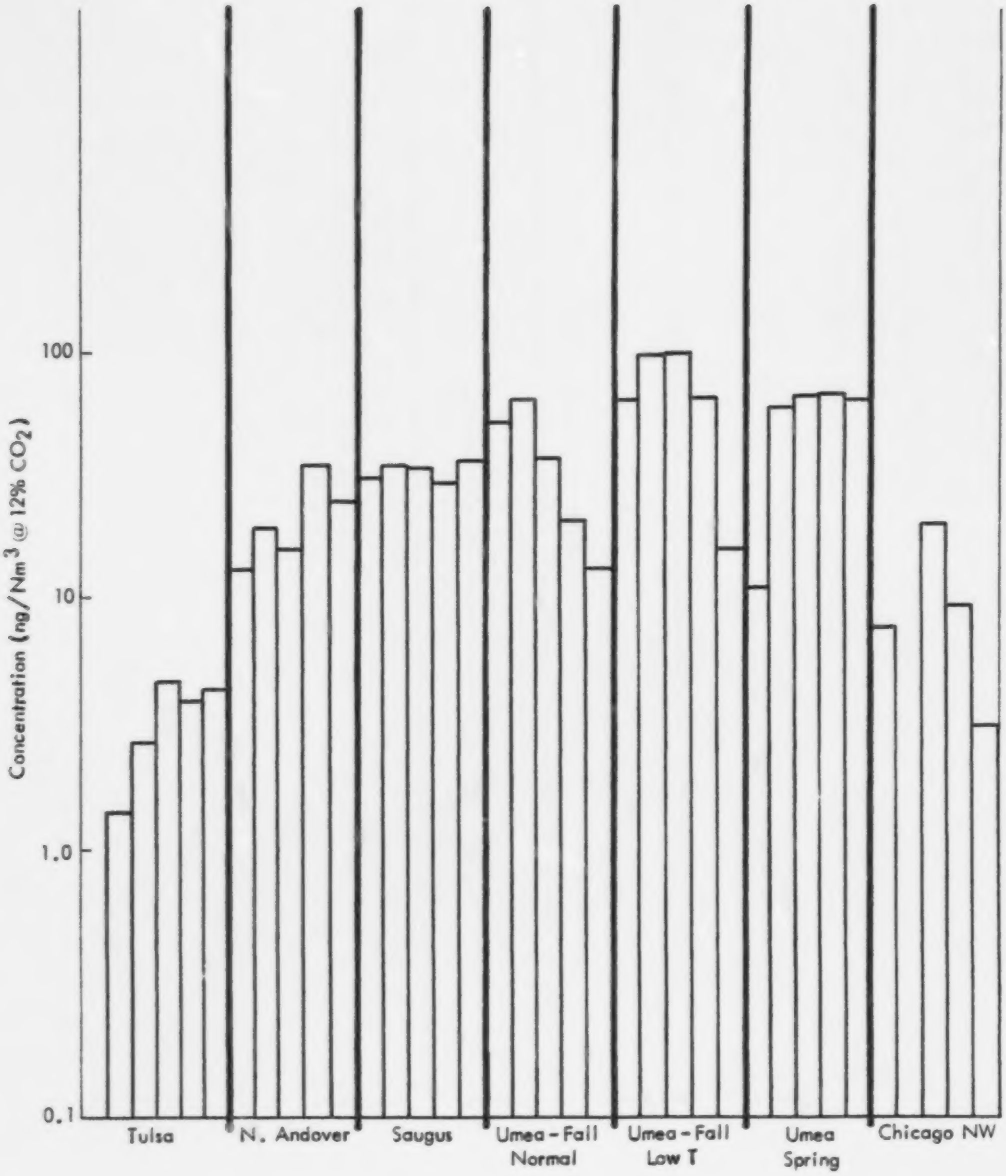
Figure 2-1. Comparison of PCDD/PCDF concentrations to average CO concentrations.

Parametric and nonparametric correlation analyses were used to compare PCDD and PCDF emissions to primary chamber, secondary chamber, and stack temperatures at Hamilton-Wentworth. Emissions also were compared to temperature differences between the measurement points. No significant relationships were identified. On the other hand, total PCDD/PCDF concentrations at Prince Edward Island were found to be correlated inversely with secondary chamber temperatures.

The distribution of PCDD and PCDF emissions among the different homolog groups is important because it has an impact on the risk associated with the emissions. The preliminary analyses of these distributions included review of the plots of the distributions to identify patterns in the data and to identify those distributions that were markedly different from the patterns. (The plots for the mass-burn systems are shown in Figures 2-2 through 2-7 as examples.) Test reports then were reviewed to identify potential reasons for the differences.

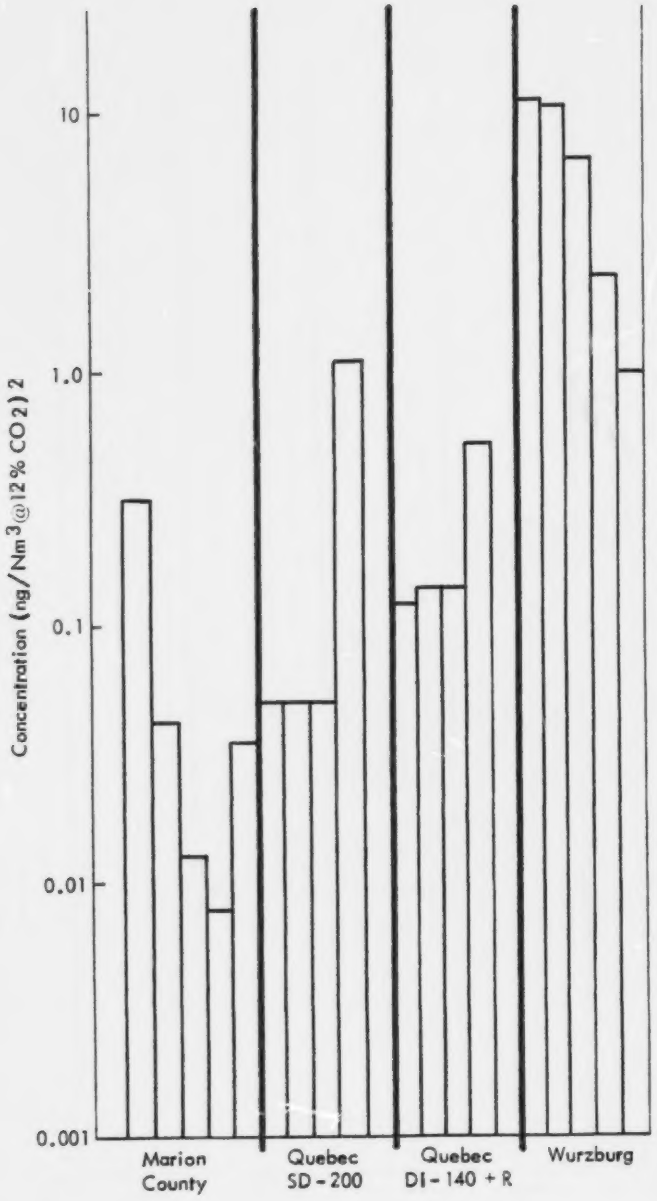
The findings related to the PCDD/PCDF distributions are summarized in Table 2-7. The review of the test reports yielded little information that could help explain the differences in the homolog distributions. Generally, the process data presented in the reports were not adequate to allow detailed site-to-site comparison of operations. Because process data were limited, the comparison of the sites focused on stack gas parameters (moisture, temperature, HCl concentrations, and O_2 concentrations) and on possible differences in the test methods. Almost all of the facilities that differed from the norm were tested with the draft ASME protocol or comparable methods, so differences in the homolog distributions cannot be explained by test method variations. Also, few differences were found in the stack gas parameters among sites. Consequently, those parameters did not lend much insight into possible reasons for the differences in distributions. The limited findings from the review are summarized below.

Little information was found that could help explain the differences in either PCDD or PCDF distributions for mass-burn incinerators. However, two observations may be of interest. The distributions of PCDD at Wurzburg and Tulsa (skewed toward higher chlorinated homologs) are significantly different than the distribution at Marion County (abnormally



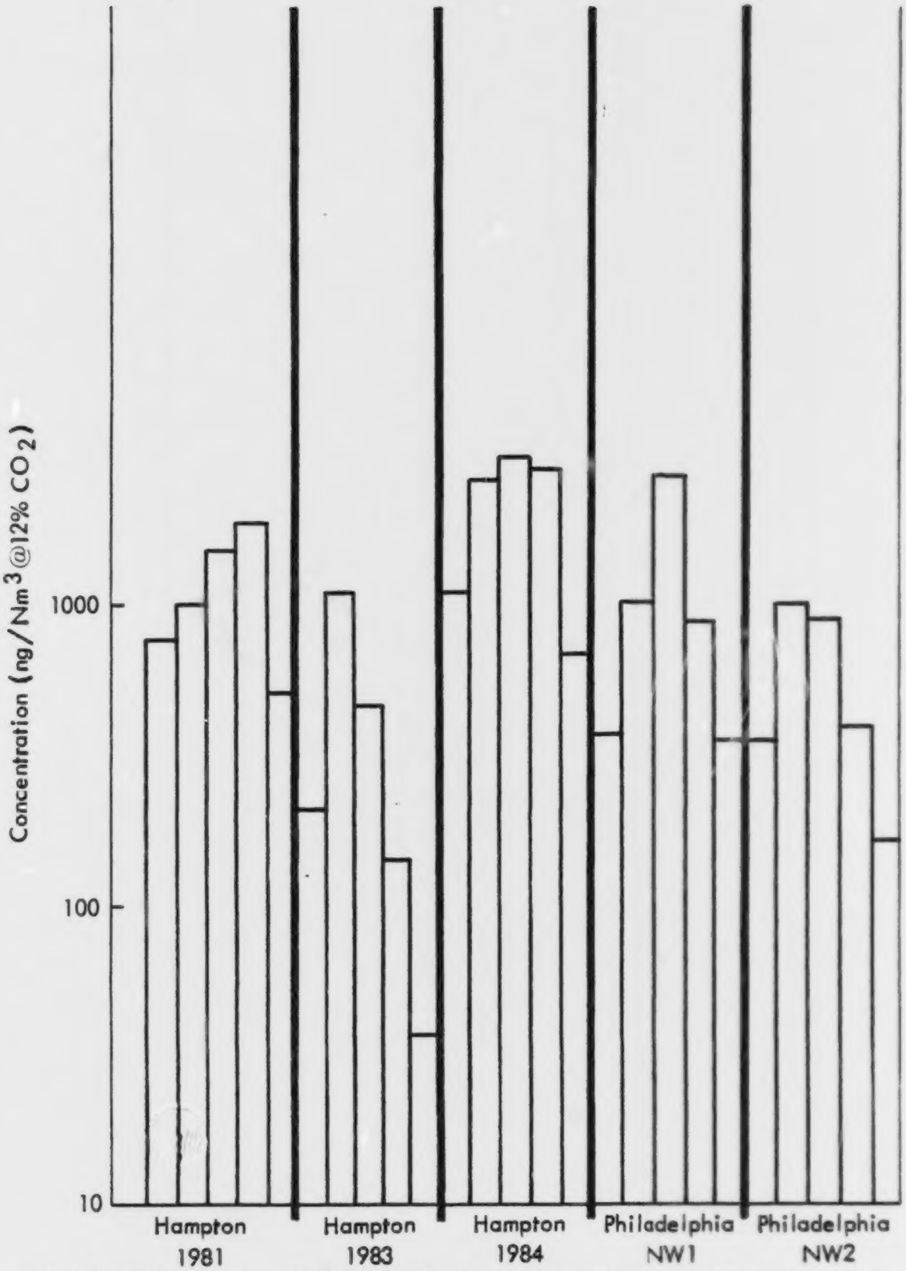
Vertical bars from left to right represent tetra through octa homologs, respectively. No penta homolog data were reported for Chicago NW.

Figure 2-2. PCDD homolog distributions--mass burn with ESP control.



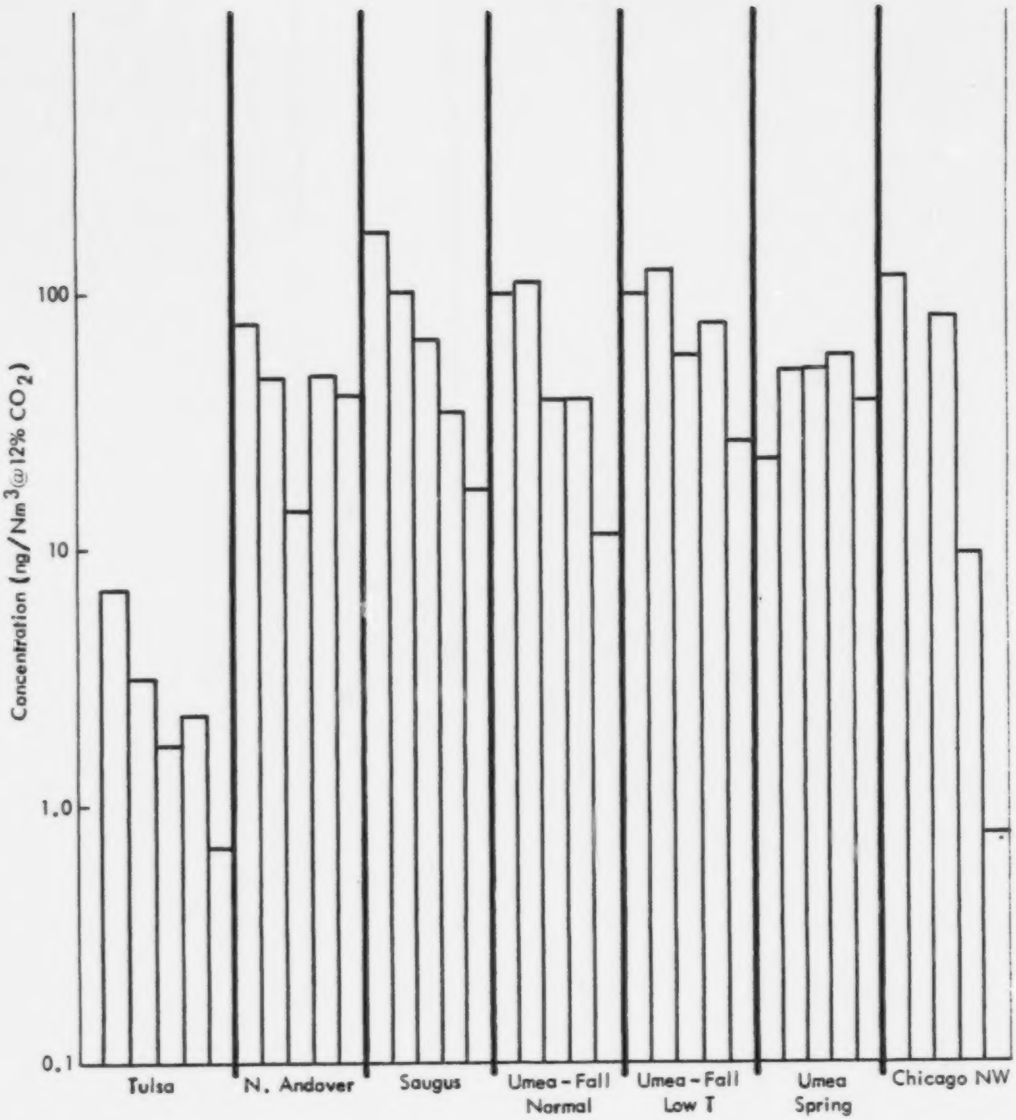
Vertical bars from left to right represent tetra through octa homologs, respectively. Blanks indicate that the homolog concentration was below the detection limit.

Figure 2-3. PCDD homolog distributions--mass-burn MWC's with DS/FF controls.



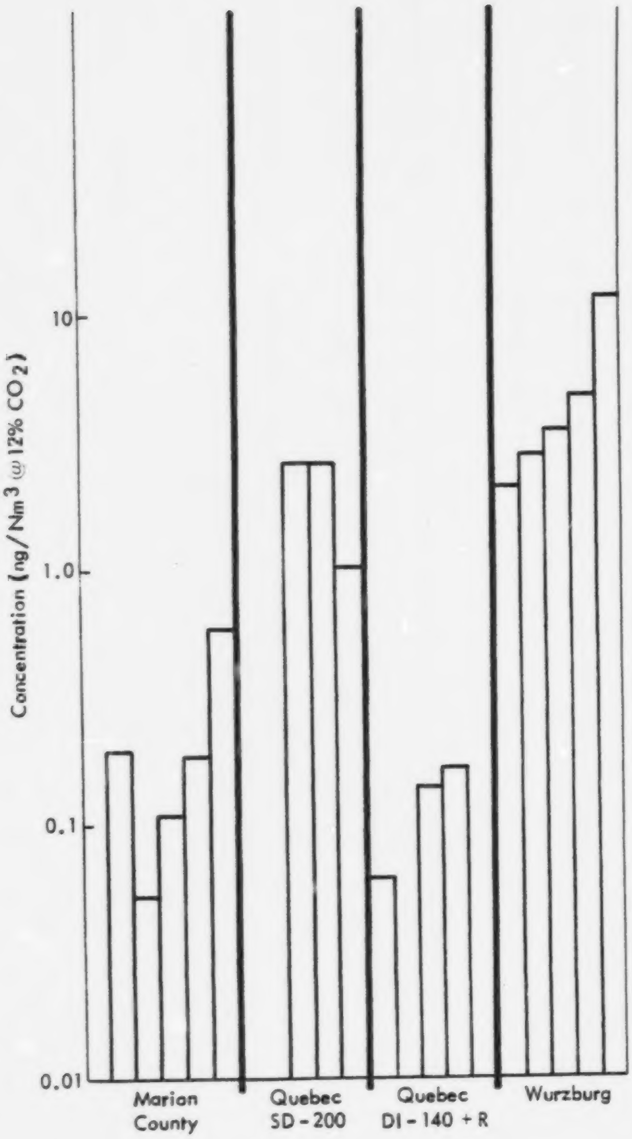
Vertical bars from left to right represent tetra through octa homologs, respectively. Blanks indicate that the homolog concentration was below the detection limit.

Figure 2-4. PCDD homolog distributions--mass-burn MWC's with high emissions.



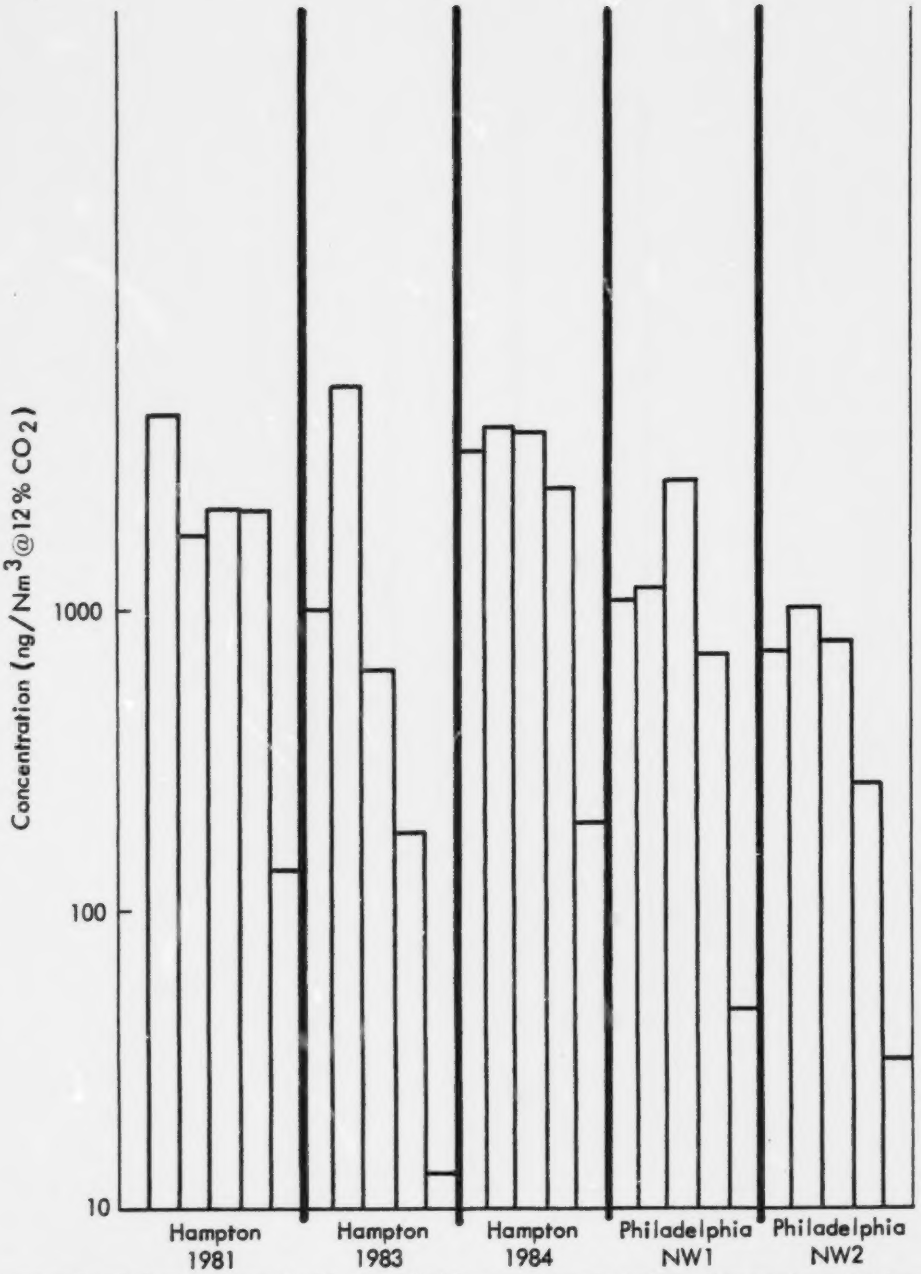
Vertical bars from left to right represent tetra through octa homologs, respectively. No penta homolog data were reported for Chicago NW.

Figure 2-5. PCDF homolog distribution--mass-burn MWC's with ESP controls.



Vertical bars from left to right represent tetra through octa homologs, respectively. Blanks indicate that the homolog concentration was below the detection limit.

Figure 2-6. PCDF homolog distribution--mass-burn MWC's with DS/FF controls.



Vertical bars from left to right represent tetra through octa homologs, respectively. Blanks indicate that the homolog concentration was below the detection limit.

Figure 2-7. PCDF homolog distributions--mass-burn MWC's with high emissions.

TABLE 2-7. PRELIMINARY FINDINGS RELATED TO HOMOLOG DISTRIBUTIONS

- PCDD
  - Mass burn
    - Generally symmetric with highest levels in penta, hexa, or hepta homologs
    - Saugus almost uniform
    - Tulsa, Umea (spring), Wurzburg skewed to high Cl
    - Marion County, Umea (fall) have abnormally high tetra
  - Modular
    - Generally skewed to high Cl
    - Red Wing has low OCDD
  - RDF
    - Generally symmetric with some tests fairly uniform
    - Three of the Hamilton-Wentworth tests skewed to low Cl
- PCDF
  - Mass burn
    - Generally skewed to lower Cl
    - Umea (spring) skewed to higher Cl
    - Quebec (controlled) skewed to high Cl but (uncontrolled) to low Cl
    - N. Andover uniform
  - Modular
    - Generally symmetric
    - Cattaraugus skewed to low Cl
  - RDF
    - Generally skewed toward low Cl
    - WPAFB has high tetra but low penta and hexa homologs

high TCDD). In contrast to the differences in homolog distributions, the three facilities are quite similar with respect to design and operation. All three facilities are Martin systems with state-of-the-art computerized controls. The major difference in the systems is that Wurzburg and Marion County have acid gas controls and Tulsa has only an ESP. In addition to the similarity of design, the systems were tested with similar test methods, and the stack gas characteristics are quite similar. The differences in emission characteristics from these three sources that appear to be quite similar in both design and operating conditions highlight the difficulties in comparing PCDD and PCDF emissions from site-to-site.

The differences in the inlet and outlet PCDF distributions at Quebec City also are of interest. The inlet distribution is similar to the distributions at other MWC's and exhibits higher concentrations of the lower chlorinated homologs while the outlet has higher concentrations of the more highly chlorinated homologs. These data suggest that the pilot-scale DS/FF systems at Quebec City were more effective in controlling less chlorinated homologs. However, since no inlet/outlet data are available for full-scale dry scrubbing systems, this finding should not be generalized to other dry scrubbing systems.

The review of the test reports for the modular and RDF-fired facilities did not yield any information that could explain the differences in either PCDD or PCDF distributions. All three modular systems are of Consumat design and operate with comparable stack gas characteristics. The three test series at Hamilton-Wentworth that were skewed to the lower chlorinated PCDD homologs did not have distinctly different stack gas characteristics from the other four test series.

2.2.2 Metals Analyses

Metals emissions from MWC's obviously depend on the metals content of the waste feed. Unless detailed, reliable information on the waste feed composition is available, the site-to-site variation in metals emissions cannot be evaluated. However, even if waste feed data are not available, the relative performance of add-on control devices can be evaluated if inlet/outlet emission data are collected. The paragraphs below describe the performance data that are included in the data base.

✓

Data on control device performance for seven metals are summarized in Table 2-8. These data were collected from five facilities. Baltimore has a four-field ESP that has demonstrated the highest level of PM control on an MWC in North America. Braintree was an older MWC that is now shut down. The ESP was reported to have operating problems, and the overall PM efficiency of this system of 76 percent certainly indicates that the ESP was substandard. The Tsushima facility has a quench reactor/dry venturi/FF control system. The Tuscaloosa facility has an ESP that was in poor operating condition at the time of the test. Malmo has a DS followed by an ESP and FF in sequence.

Since two of the facilities have reportedly substandard control systems, the data presented in Table 2-8 are quite limited, and no conclusions about the relative effectiveness of metals control can be developed. However, three observations may be of interest. These observations are based on the relative enrichment or depletion of metals emissions in comparison to particulate matter emissions across a control device. Metals are said to be enriched in the particulate stream when the ratio of metals emissions to particulate matter emissions is greater at the control device outlet than at the control device inlet. They are said to be depleted when the ratio at the outlet is lower than the ratio at the inlet.

First, the enrichment of both As and Cr in the outlet particulate at Baltimore is much higher than at any of the other facilities. Since Baltimore does have an extremely high PM collection efficiency (99.9 percent), the data indicate that these metals, particularly As, are likely to be concentrated in the fine particle fraction of MWC PM emissions. Second, the Cd enrichment at Tsushima is much greater than that at Malmo. This difference may be influenced by the higher temperature at the inlet to the control system at Tsushima. Finally, the Hg enrichment at Malmo and Tsushima suggests that even though dry scrubbing systems provide some level of Hg control, significant quantities pass through the system in the gas phase or the fine particle fraction.

TABLE 2-8. SUMMARY OF METALS ENRICHMENT/DEPLETION

Facility	Pollutant	Metals concentration, μg/g PM In	Metals concentration, μg/g PM Out	Ratio, out/in
Baltimore	As	51.2	1,020	20
Braintree	As	63.8	83.9	1.3
Tsushima	As	13.8	11.9	0.86
Tuscaloosa	As	605	308	0.51
Braintree	Be	0.041	0.156	3.8
Tsushima	Be	10.5	11.9	1.1
Braintree	Cd	563	870	1.5
Malmo	Cd	155	268	1.7
Tsushima	Cd	26.9	412	15
Baltimore	Cr	465	3,450	7.4
Braintree	Cr	280	194	0.69
Tsushima	Cr	605	195	0.32
Tuscaloosa	Cr	186	181	0.97
Braintree	Pb	15,200	28,200	1.9
Malmo	Pb	3,210	5,650	1.8
Tsushima	Pb	631	758	1.2
Braintree	Hg	12.8	73.3	5.7
Malmo	Hg	70.1	8,060	110
Tsushima	Hg	59.5	6,770	110
Tsushima	Ni	512	10,800	21

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3. DESCRIPTIONS OF MWC FACILITIES

3.1 PROCESS DESCRIPTIONS AND TEST PROTOCOL SUMMARIES

Process description and test protocol summaries are presented below by combustor type in the following order: mass-burn, excess-air MWC's; modular, starved-air MWC's; and RDF-fired MWC's. Each summary contains a brief description of the combustor, the air pollution control system, and the sampling and analysis protocol employed at the test site.

3.1.1 Baltimore, 1985 Tests (Mass Burn, Waterwall)[1,2]

The Baltimore facility consists of three, identical, 686-Mg/d (750-ton/d), mass-burn, waterwall combustor units, which were installed in 1984. Each combustor has its own 91,400-kg/h (200,000-lb/h) steam heat recovery boiler. A portion of the steam drives a 60-MW turbine generator. Nonprocessed waste is transferred by overhead cranes from the contained pit to the feed hopper where ram feeders charge the waste onto Von Roll reciprocating grates. Overfire and underfire air is drawn from the pit area to fuel the combustion process. Furnace temperatures are between 1200° and 1370°C (2200° and 2500°F). Bottom ash and ESP ash are combined onto a semidry, vibrating-pan conveyor and processed through a screen and magnetic separator prior to disposal.

Particulate emissions are controlled by three, conventional, wire/plate ESP's, each designed by Wheelabrator Frye with four fields. The three ESP exhaust streams are separately ducted and routed through an induced-draft (ID) fan into a common stack.

Compliance testing was performed in January 1985 on Unit 1 under normal operating conditions. Emission measurements included: (1) PM by M5; (2) SO_2, fluorides, and solid chlorides by a modified M8 train with analysis by M8, EPA Method 13B (M13B), and mercuric nitrate titration, respectively; (3) gaseous chlorides by a modified EPA Method 6 (M6) with analysis by mercuric nitrate titration; (4) NO_x by EPA Method 7 (M7); and (5) CO by EPA Method 10 (M10) with sample analysis by flame ionization detection with gas chromatography (FID/GC).

Tests were conducted on Unit 2 while it was operating normally at approximately 85 percent of capacity during May 1985. These tests were conducted by EPA's Emission Measurement Branch (EMB) to measure chromium emissions. Uncontrolled and controlled emission testing included PM by EPA M5; inorganic As by EPA M108; Cr^{+6} by digesting M5 filters in an alkaline solution with analysis by the diphenylcarbazide colorimetric method; total Cr, Cd, and Ni by neutron activation analysis (NAA); and particle sizing with an Andersen Mark III impactor and an Andersen heavy grain loading impactor/cyclone. Metal analyses included filter and impinger solutions for As and filter only for total Cr, Cr^{+6}, Cd, and Ni.

3.1.2 Braintree, 1978 Test (Mass Burn, Waterwall)[3]

The Braintree municipal incineration facility comprised two, identical, mass-burn, waterwall incinerators. The facility is no longer in operation. Each incinerator was designed to handle 109 Mg/day (120 tons/day) at a charge rate of 1,090 kg/charge (2,400 lb/charge). The refuse was charged by gravity onto an inclined grate, where drying occurred, and then onto a Riley Stoker horizontal traveling grate, where combustion occurred. The burn grate was designed for a heat release rate of 3,240 MJ/m^2h (285,000 $Btu/h \cdot ft^2$). The grate was supplied with underfire air from a forced-draft (FD) fan; typically, no overfire air was used. The hot gases passed to the Riley Stoker boiler that had 83 m^2 (890 ft^2) of waterwall heating surface and boiler tubes with a heating surface of 224 m^2 (2,410 ft^2). The boiler had a capacity of 13,600 kg/h (30,000 lb/h) of 1,720 kPa (250 psig) steam.

The exhaust gases from each incinerator were directed to ESP's. A bypass duct that connected the inlets of the two ESP's allowed the exhaust from an incinerator to be directed to either or both ESP's. The ESP's were identical, single-field Wheelabrator-Frye units. Each had a specific collection area (SCA) of 413 $m^2/1,000\ m^3/min$ (126 $ft^2/1,000$ acfm) and a design collection efficiency for PM of 93 percent. No data were presented on ESP operating conditions during the test.

The metals testing at Braintree was conducted as a part of a comprehensive environmental assessment of the facility. Key elements of the program included quantitation and characterization of the refuse feed, bottom ash, and ESP outlet PM and gases. The ESP inlet PM also was measured. Three tests, all at normal operating conditions, were conducted.

At the inlet to the ESP, PM concentrations were determined using M5, and particle size measurements were made with a Brink impactor. The particulate filters from the M5 tests were analyzed for As, Hg, Pb, and Cd using spark source mass spectroscopy (SSMS) and AA. At the outlet of the ESP, PM concentrations were determined using M5, and particle size distributions were determined by an Andersen cascade impactor. The M5 filters were analyzed for metals using SSMS and AA. In addition, an impinger train that contained potassium hydroxide (KOH) in the first impinger and $KMnO_4$ in the second and third impingers was used to sample for vaporous Hg at the ESP outlet. The KOH impinger also was analyzed for concentrations of chloride and fluoride. A SASS train was used during one test at the ESP outlet. The impinger solutions from the SASS train were analyzed for volatile As and Hg. Mercury concentrations in the impinger train and SASS train were determined by cold vapor generation AA, and As concentrations were determined by a hydride generation AA technique.

Continuous analyzers were used to measure stack concentrations of CO by nondispersive infrared spectrophotometry (NDIR), total hydrocarbons (THC) by FID, SO_2 by NDIR, NO_x by chemiluminescence, and O_2 by polarographic cell.

3.1.3 Chicago Northwest, 1980 Tests (Mass Burn, Waterwall)[4]

The Chicago Northwest incineration plant consists of four, mass-burn, waterwall incinerators, each with a nominal burning capacity of 363 Mg/day (400 ton/day). To charge the furnace, waste feed is transferred by crane to the charging chute, fed by gravity onto three stoker feeders, and pushed onto the stoker by the reciprocating action of the stoker feeders. In the combustion chamber, the waste is moved through the system by a series of Martin, inclined, reverse-action reciprocating grates. The stokers are designed to use 1,900 Nm^3/min (67,200 scfm) of primary underfire air at 4.5 kPa (18 in. w.c.) and 476 Nm^3/min (16,800 scfm) of overfire air at 3.7 kPa (15 in. w.c.). Underfire air is introduced into multiple compartments under the stoker grates; distribution is manually controlled. Overfire air is supplied through the front and rear walls. The system is designed to produce 49,900 kg/h (110,000 lb/h) of steam at 1,720 kPa (250 psig) and has an average stoker heat release rate of 3,770 $MJ/h{\cdot}m^2$ (325,000 $Btu/h{\cdot}ft^2$). The boiler is a convection, waterwall, natural-circulation type with economizer that has 1,840 m^2 (19,800 ft^2) of heating surface.

The air pollution control device for Unit 2 is a plate-type ESP. It is designed for a collection efficiency of 97 percent at an inlet grain loading of 3,600 mg/Nm^3 (1.6 gr/scf). The design inlet temperature is 260°C (500°F), and the superficial gas velocity is 0.9 m/s (3 ft/s).

The testing at Chicago included outlet sampling for organic pollutants and Cd on Unit 2. Organic sampling was conducted using the EPA MM5 sampling train, and Cd samples were collected in an M5 sampling train. Stack gases also were monitored continuously for O_2, CO_2, CO, and THC (C_1 through C_6 hydrocarbons). The M5 filter was digested, and Cd analyses were conducted with flame AA using an air-acetylene flame.

3.1.4 Hampton, 1981, 1982, 1983, 1984 Tests (Mass Burn, Waterwall)[5-8]

The Hampton facility consists of two, mass-burn, waterwall incinerator-boilers. Each unit is designed to handle approximately 114 Mg/day (125 tons/day), producing steam at 15,000 kg/h (32,000 lb/h). Refuse is moved from a storage pit to the feed hopper by an overhead crane and transferred through the furnace by a series of three, inclined reciprocating grates. The furnace is designed to burn refuse without auxiliary fuel. Unburned residue is discharged into a waterfilled quench pit. Particulate matter removed from the flue gas also is conveyed to the quench pit. The pit is continuously dredged into a truck for landfill disposal. During stable operation, the firebox temperature is near 1260°C (2300°F), and the furnace wall temperature ranges from 790° to 840°C (1450° to 1550°F).

The facility is equipped with an ESP. Hot furnace flue gas, after traveling through economizers, goes to the ESP where PM is removed. A conveyor discards ESP ash to an ash pit, and the gas from the ESP is routed to an ID fan and out the stack.

Tests were conducted in September 1981 to evaluate measurement methods for sampling chlorinated hydrocarbons, gaseous HCl, and particulate chloride.[6] The feed rate was 112 Mg/day (123 tons/day) during the test period. Process conditions were not reported. Organic compounds were sampled using a MM5 train with glass beads in the first two impingers and an XAD-2 sorbent resin cartridge located between the third and fourth impingers. Organic compound analysis was performed with high resolution gas chromatography/high resolution mass spectroscopy (HRGC/HRMS) to measure (1) tetra- through octa-CDD and CDF homologs; (2) di- through hexa-ClB homologs; (3) tri- through penta-ClP homologs; and (4) tri- through hexa-homologs of PCB. An EPA M6 train with sodium hydroxide (NaOH) in all four impingers was used to measure HCl. Analysis for HCl was performed by the mercu[illegible]itrate method modified by treating the sample with hydrogen peroxide H_2O_2.

Testing was performed in April 1982 to characterize stack emissions during normal operation at an estimated feed rate of 114 Mg/day (125 tons/day).[7] Detailed data on process operation were not available. Comprehensive emission measurements included: (1) PM by M5; (2) particle size with an Andersen impactor; (3) particle-phase metals from cyclone/filter catch from a SASS train by XRF (As, Cd, Cr, Hg, Pb, and Ni) and SSMS (Be only); (4) volatile metals (As, Hg, Pb, et al.) from SASS impingers with H_2O_2 followed by ammonium persulfate/silver nitrate solutions by AA analysis; (5) HCl and HF by an M6 train with NaOH solution in first two impingers by ion chromatography (IC); (6) polyaromatic hydrocarbons (BaP, et al.), 2,3,7,8 TCDD/TCDF and total TCDD/TCDF with SASS cyclone, filter, and XAD-2 resin catch by HRGC/MS; (7) anions in flyash (sulfate, nitrate, chloride, bromide, flouride, and phosphate) with SASS impingers with distilled water by IC; (8) aldehydes (formaldehyde, et al.) with an M6 train with HCl, 2,4-dinitrophenyl-hydrazine, and isooctane in first two impingers by reverse-phase high-performance liquid chromatography (HPLC); and (9) volatile hydrocarbons (benzene, et al.) and chlorinated organic compounds (chlorobenzene isomers/homologs, et al.) using EPA Method 25 (M25) equipment quantitated by FID and electron capture detection (ECD), respectively. Organic screening analysis to estimate concentrations of various compounds was performed by HRGC/MS from aliquots of the sample extracts, but the reported estimates were not included in the EPA data base.

Testing was performed in 1983 as part of a nationwide survey to determine organic emissions from major stationary combustion sources.[4] The unit was tested under normal conditions with variations in steam flow from 13,600 to 15,400 kg/h (30,000 to 34,000 lb/h) and furnace temperature from 700° to 930°C (1300° to 1700°F). Process and ESP operating conditions were monitored and reported, and continuous emission monitoring for O_2, CO_2, CO, and THC was conducted. Sampling was performed with a MM5 train with a condenser and an XAD-2 resin cartridge located between the filter box and first impinger. Quality assurance and quality control (QA/QC) included surrogate spiking, surrogate recovery, blank samples, and analyte breakthrough tests. Analyses were by HRGC/MS, high resolution gas chromography/mass spectroscopy-selected ion monitoring (HRGC/MS-SIM), and HRGC/HRMS-SIM. Emission results were reported for mono- through tetra-CDD and CDF homologs and 2,3,7,8-TCDD, BaP, and mono- through deca- homologs of PCB.

Testing was also performed in October 1984 to determine any changes in emission characteristics since the installation of an air preheater and a CO continuous monitor.[6] The incinerator was tested during normal operation with a steam flow of 12,500 kg/h (27,500 lb/h) and furnace temperature near 820°C (1500°F). The process operation was monitored and process data were reported in the appendix to the test report, but these data have not yet been included in the EPA data base. Emission results were reported for the tetra- through octa-CDD and CDF homologs, di- through hexa-ClB homologs, and tri- through penta-ClP's. Sampling was performed with an MM5 train with glass beads in the first two impingers and an XAD-2 resin cartridge located between the third and fourth impingers. All analyses were by HRGC/HRMS.

3.1.5 Tulsa, 1986 Test (Mass Burn, Waterwall)[9]

The Tulsa facility currently consists of two, identical, 343-Mg/d (375-ton/d), mass-burn, waterwall combustor units, which were installed in 1986. Each combustor has its own steam heat recovery boiler, portions of which drive a turbine generator. Nonprocessed waste is transferred by overhead cranes into the feed hopper where the waste is charged onto Martin GmbH, inclined, reverse-reciprocating grates.

Particulate matter emissions are controlled by two ESP's. The two ESP exhaust streams are routed into a common stack.

Compliance tests were conducted on Units 1 and 2 during normal operation to determine controlled emission levels for: (1) PM by EPA M5; (2) Pb, Be, and Hg by EPA Methods 12 (M12), 104, and 101A (M101A), respectively; (3) No_x and CO by EPA Method 7E (M7E) and M10, respectively; (4) H_2SO_4, SO_2, HF, and HCl by EPA M8 and Method 13A (M13A); (5) volatile organic compounds (VOC) by California Air Resources Board Method 100; (6) opacity by EPA Method 9 (M9); and (7) trace chlorinated organic compounds by an MM5 train as specified by the ASME draft protocol. Separate emission measurements were made for each pollutant on Units 1 and 2, with the exception that measurements for Hg, trace chlorinated organic compounds, and opacity were made at the stack common for both units. Front- and back-half M5 determinations were made to measure the amount of particulate and condensible matter, respectively. The M5 impinger liquid was analyzed to determine the amount of ammonium sulfates, inorganic chlorides, and fluorides. The M5 filter and impinger liquid were both analyzed to determine HF and HCl levels. Emissions of Pb and Be were measured by modifying EPA M12 by charging the first impinger with distilled water and the second impinger with dilute aqua regia.

3.1.6 Peekskill, 1985 (Mass Burn, Waterwall)[10]

The Westchester facility in Peekskill, New York, consists of three, identical boilers, each of which has a design capacity of 76,000 kg (167,700 lbs) of steam per hour at 440°C and 6,200 kPa (830°F and 900 psig) from the combustion of 682 Mg (750 tons) of refuse per day. The Von Roll reciprocating-grate mass burners are fed uniformly by a ram system, which is in turn fed at random by grapplers. Primary air is introduced from beneath the grates while secondary air is introduced through nozzles located above the grates. The refuse is combusted on licensed Von Roll grates in the furnace, which operates at temperatures exceeding 980°C (1800°F). Odor from the refuse pit area is controlled by drawing combustion air from the pit area to maintain negative pressure over the pit. Electricity is produced by a turbine generator that is driven by superheated steam from a waterwall boiler above the grate area.

Each boiler is serviced by a three-field ESP designed to keep particulate emissions below 68 mg/Nm^3 (0.03 gr/dscf) at 12 percent CO_2. From the ID fans, the gases are fed into three separate flues within the single stack.

Sampling at the plant was conducted on Unit 1 during April 1985 in the ductwork between the ESP's and ID fans. Throughout testing, the unit operated at 95 to 112 percent of design capacity. Concentrations of the following compounds were measured during the normal operation of the plant:

PM
2,3,7,8-TCDD
2,3,7,8-TCDF
PCDD (tetra-octa)
PCDF (tetra-octa)
Chrysene
PCB
BaP
Formaldehyde
HCl
As
Be
Hg
Cd
Cr
Pb
Manganese
Ni
Vanadium
Zinc
SO_2
NO_x
CO
CO_2
O_2

Measurements for criteria and other pollutants were performed using applicable EPA reference methods. Measurements for PCDD/PCDF were made using the ASME draft protocol. The organics train consisted of a glass-lined probe, a heated glass-fiber filter, a cooling condenser, a water-cooled glass cartridge containing 40 g of XAD-2 resin, and several glass impingers. All sections of the train were glass and were connected by Teflon™ unions except the 316 stainless steel nozzle. The resin was spiked before sampling with a known quantity of isotopically tagged 1,2,3,4-TCDD to determine retention efficiency.

3.1.7 Gallatin, 1983 Tests (Mass Burn, Waterwall)[11]

The Gallatin facility fires unprocessed municipal waste to two, 91-Mg/day (100-ton/day), O'Connor, water-cooled rotary combustors. Waste received at the facility is transferred to the feed hoppers by overhead cranes and then fed to the combustor by a ram-feed system. The inclined combustor rotates between 10 and 20 revolutions per hour (rph) to process the refuse through the combustion zone. Combustion air is preheated to

230°C (450°F) and is fed as both underfire and overfire air in the rotary combustor and as overfire air to the boiler zone. The rotary combustor is mated to a Keeler waterwall boiler for radiative and convective heat transfer. The boiler is designed to produce 12,000 kg/h (27,000 lb/h) of steam at 2,930 kPa (425 psig).

At the time of the test, the emissions from the Gallatin facility were controlled by a cyclone and an electrostatically assisted FF. The FF was an innovative technology that was eventually replaced with an ESP due to several problems associated with the unit. No other design information on the control system was provided in the report.

Particle size distribution and heavy metals emission rates were determined at the outlet from the combustor using a Flow Sensor, five-stage, multiclone sampling system. A total of four runs, each about 1.5 hours in duration, were made. After the cyclone catch from each stage was weighed for particulate loadings, metals analyses were conducted using AA. Those metals analyzed were As, Be, Cd, Cr, Ni, and Pb. Four separate tests at the combustor outlet measured Hg using M101 with analyses by AA. In addition to particulate and metals measurements, emission rates of SO_2 and SO_3 were determined using EPA M8. The HCl and HF rates were measured with an M6-type train. A continuous emission monitoring system was used to measure stack gas concentrations of O_2 (paramagnetic), CO and CO_2 (NDIR), NO_X (chemiluminescence), SO_2 (ultraviolet), and total nonmethane hydrocarbons (GC/FID).

3.1.8 Kure, Japan, 1981 Test (Mass Burn, Waterwall)[12]

The Kure facility consists of two, 75-Mg/day (165-ton/day), mass-burn, O'Connor, water-cooled rotary combustors equipped with separate waterwall boilers. The facility began commercial operation in November 1980. Two cranes mix the solid waste and deposit the loads into the feed chutes for each of the combustors. The ram behind the entrance to the rotary combustor pushes the solid waste from the bottom of the feed chute into the rotary combustor on a scheduled cycle that sets the volumetric feed rate. As the solid wastes are combusted, they are mixed by the rotation of the combustor barrel (10 to 20 rph) and moved the length of the rotary combustor. The bottom ashes pass through the base of the boiler on a small traveling grate into a quench tank, then along a conveyor into the ash pit. A crushing plant recovers recyclable materials after crushing and shearing the bulky waste and delivers the remaining waste material by conveyor to the solid waste receiving pit for combustion in the rotary combustors. Combustion gas passes through the boiler, FD fan, and combustion air preheater.

The air pollution control system consists of an ESP followed by a wet scrubber. The ESP was manufactured by Ishipawajima-Harima Heavy Industries Company, Ltd. The wet scrubber has a turbulent contacting absorber design.

Testing was performed on Unit 1 and consisted of a comprehensive evaluation of waste feed combustor process parameters along with uncontrolled and controlled emission measurements. Emission measurements included: PM by M5; SO_2 and SO_3 by M6 and M8; NO, NO_x, O_2, and SO_2 by continuous emission monitors (CEM's); hydrocarbons by GC/FID after collection in charcoal tubes and metal bombs; and particle sizing with an Andersen impactor. Heavy metals were analyzed for the different particle size ranges by emission spectrophotometry and from M5 filters by NAA. Measurement methods for HCl and HF were not described in detail.

3.1.9 Munich, 1984 Tests (Mass Burn, Waterwall)[13]

The Munich North III MWC facility consists of two, mass-burn incinerator-boiler units, each designed to burn 480 Mg/day (530 tons/day) of municipal waste and 260 Mg/day (290 tons/day) of clarified sludge to produce 50,000 kg/h (110,000 lb/h) of steam. A hydraulic ram located under the feed chute charges the waste onto reciprocating grates. Combustion airflow is controlled by an inlet damper on the primary air fan. The firing rate is controlled by O_2 and temperature monitors in the first boiler pass, which regulate the refuse feed rate and combustion airflow. The refuse feed rate is determined by the stoke rate of a hydraulic feeder under the feed chute. Air flow is controlled by an inlet damper on the primary air fan. The bottom ash falls off the end of the grate into a water quench ash extractor. A bar grizzly at the extractor discharge separates oversize materials (mostly metal) from the ash, which is transported by belt conveyor to the ash bunker. The oversize material is manually removed to a dumpster.

The emission control system consists of a DBA SD reactor followed by a DBA ESP. Flue gas from the boiler enters the SD at about 260°C (500°F). The lower inlet section of the SD is a cyclonic preseparator where approximately 70 percent of the fly ash is removed from the flue gas and pneumatically transported to the ash bunker. From the preseparator section, the flue gas flows upward through a distribution grid and into 10 flow tubes arranged annularly on the reactor perimeter. Each tube contains a dual-fluid nozzle used for spraying the lime slurry into the gas stream. The atomized lime slurry, which is a composite of concentrated lime slurry and dilution water, is prepared from calcium oxide (CaO) in a slaker. The acid gases are removed from the flue gas by an absorption-reaction process while the water component of the droplet is evaporated. The result is a dry particulate which includes calcium salts and excess lime. The evaporation process lowers the temperature of the flue gas to approximately 150°C (300°F). The solid reaction products from the SD reactor, together with the dust that has passed through the cyclone, are carried over into a two-field ESP and removed from the flue gas. The collected material is mechanically and pneumatically transported to the ash bunker. The ESP exhaust is routed through an ID fan and a concrete stack.

The intent of the test program was to establish the ability of the control system to maintain air pollutant emissions at levels acceptable in the U.S. Test conditions were selected to optimize the emission control system performance over a range of SD operating conditions but were limited during testing by certain plant operating requirements. During these tests, only MSW was fired. Uncontrolled and controlled emission testing was performed for PM, particle size distribution, HCl, and SO_x. Controlled emission tests were conducted for several selected metals, including As, Be, Cd, Cr, Pb, and Ni. The sampling and analysis methods used in the test were: (1) M5 for PM; (2) M8 for SO_2 and SO_3; (3) M6 for HCl, modified by using distilled water in the impingers; (4) particle sizing with an Andersen cascade impactor and three-stage Flow Sensor multiclone; and (5) heavy metals with Flow Sensor multiclone sampling and AA analysis.

3.1.10 Quebec, 1985-86 Pilot-Scale Tests (Mass Burn, Waterwall)[14]

The Quebec incinerator is a mass-burn design developed in the early 1970's to burn as-received refuse in a waterwall furnace. There are four incinerators, each rated at 227 Mg/day (250 tons/day) with a common refuse storage pit and stack. Each incinerator consists of a vibrating feeder-hopper; feed chute; drying/burning/burn-out grates (Von Roll design); refractory-lined burning zone; waterwalled, partially lined upper burning zone; waste heat recovery boiler with superheater and economizer (Dominion Bridge); two-field ESP; an ID fan; and wet ash quench/removal system. The incinerator receives municipal, commercial, and suitable industrial solid waste. Each of the four units is capable of independent operation and is rated to produce 37,000 kg/h (81,500 lb/h) of steam when burning 227 Mg/day of refuse with a heating value of 13,950 kJ/kg (6,000 Btu/lb).

Environment Canada in cooperation with Flakt Canada, Ltd., established an extensive test program to evaluate the capability of two pilot-scale scrubber and FF control systems to remove PM, acid gases, heavy metals, PCDD, PCDF, and other organic compounds. Evaluation of operating conditions to minimize these contaminants also were of interest. Flakt constructed a large-scale pilot facility at the Quebec plant equipped with:

1. A flue gas slipstream from the ESP inlet of Unit 3 to deliver 58 Nm^3/min (2,000 ft^3/min) at 260°C (500°F) to the pilot facility;
2. An SD--Flakt's DRYPAC design (also used as a gas cooler) with slurry spray nozzle and bottom screw conveyor;
3. A WSH/DI--Flakt's DAS design, with a single, dry hydrated lime injection nozzle and an internal cyclone integral with the scrubber at the entrance; and
4. A pulse-jet FF--Flatk's OPTIPULSE design, using high-temperature Teflon™ bags as the filtering media with an air-to-cloth ratio of 4.4 to 1.

Testing and process monitoring were conducted during normal operation of the full-scale incinerator producing 31,000 to 34,000 kg/h (68,000 to 75,000 lb/h) of steam. Key operating parameters of the pilot system were controlled and monitored at the selected test conditions. Note that these controlled conditions, particularly the constant flow rate of the slipstream, obtained during the pilot-scale testing may not be representative of the fluctuations typically experienced by full-scale operations. Uncontrolled and controlled emission measurements were performed for PCDD, PCDF, HCl, SO_2, metals (As, Cd, Cr, Hg, Pb, Ni, et al.), PCB, ClB, PAH's, and ClP.

Samples were taken at three locations: before the scrubber, between the scrubber and the FF, and at the stack of the FF. Four sampling trains were operated simultaneously during the testing. In the PM/metals/HCl train, which is based on the M5 train, gaseous HCl and metals were scrubbed by a series of water- and aqua regia-filled impingers. In the dedicated HCl train, two water-filled midget impingers were employed. Chlorides were analyzed by IC. In the Hg train, Hg was scrubbed by two impingers containing $KMnO_4$. Metals were analyzed using DCPES with these exceptions: Hg was determined by measuring the Hg vapor concentration by flameless atomic absorption (FAA), and As was determined by the formation of its hydride and analysis by FAA. In the organics train, gaseous organics were trapped in an XAD-2 resin tube and an ethylene glycol-filled impinger; analysis was by GC/MS.

Continuous gas monitoring was performed at the inlet for SO_2 (by nondispersive ultraviolet spectrophotometry [NDUV]), HCl (gas filter correlation), and THC (by FID). At the midpoint, HCl and SO_2 were continuously analyzed, and at the outlet, all of the above and CO (by NDIR) were continuously monitored.

3.1.11 Malmo, 1983 Report (Mass Burn and RDF-Fired Waterwall)[15]

The Malmo plant has two MWC units capable of burning as-received and RDF municipal waste at a rate of 10 tons/h. Each unit is designed with Martin, reverse-acting, traveling grates and Wagner-Biro two-stage boilers. The RDF processing includes a ballistic separator, a magnetic separator, and sorting and shredding equipment to produce 3,200 kcal/kg (5,200 Btu/lb) fuel. Fuel is charged through a hopper and onto an inclined grate. The refuse is dried, ignited, and combusted on the grate during transport through the furnace. Primary air is distributed through fine areas in the grate while secondary air is introduced through nozzles located on front and rear walls at the boiler entrance. Both primary and secondary air flow rates are manually adjusted for different operating conditions. Each furnace is equipped with a two-stage waste heat boiler having a nominal capacity of 32 MW. In the boilers, the flue gas is cooled from 1000° to 1100°C (1800° to 2000°F) to approximately 290°C (550°F) by circulating 540,000 kg/h (1,200,000 lb/h) of hot water which is heated from 110° to 160°C (230° to 320°F). The flue gas is further cooled in two additional boilers to improve the gas cleaning process and to increase energy efficiency.

The emission control system includes cyclones, a DI, an ESP, and an FF designed to treat 1,300 m^3/min at 220°C (46,000 acfm at 430°F). The flue gas is first directed to the cyclones, which remove approximately 60 to 70 percent of the PM. The gas then enters the reactors where lime is mixed with the flue gas. The top of the reactor is designed as an axial cyclone in which coarse lime particles are collected and then returned to the point of injection. An ESP followed by an FF collects the entrained DI particles and incinerator fly ash.

The test program was conducted to measure and compare emission control system performance during as-received waste and RDF incineration. Thirty process and control parameters were monitored by a data logger. Sampling was performed upstream and downstream of the control system for PM, HCl, CO, gas- and solid-phase metals (i.e., Cd, Hg, Pb, and Zn), medium-weight hydrocarbons (C_6-C_{18}), and polycyclic and chlorinated compounds.

Measurements for PM were performed with isokinetic extraction and collection on quartz filter fabric at 160°C (320°F). The sample gas was cooled, dried, and measured with a flowmeter and volume meter. Sampling for HCl was performed using NaOH in two impingers in series, and HCl analysis was performed by filtration with silver nitrate using an ion-selective electrode. Sampling for Hg was performed using three impingers with separate solutions of soda and $KMnO_4$ with sulfuric acid, followed by AA analysis. Sampling for Cd, Pb, and Zn was conducted using two impingers with HNO_3, and analysis was by AA. Sampling for medium-weight hydrocarbons (C_6-C_{18}) was performed by absorption tubes with Tenax™ GC with analysis by GC/FID and capillary column. Polycyclic and chlorinated hydrocarbon sampling was performed by isokinetic sampling in an all-glass train equipped a heated filter, water-cooled condenser, condensate trap, and XAD-2 resin trap. Concentrations of PCDD and PCDF were determined for three sampling train components (filter catch, XAD-2 catch, and condensate) by GC/MS using Swedish reference methods.

3.1.12 Wurzburg, West Germany, 1985 Tests (Mass Burn, Waterwall)[16]

The facility tested at Wurzburg is a new, Martin GmBH, reverse-reciprocating-grate, waterwall furnace. During the test period, refuse flow to the incinerator ranged from 260 to 280 Mg/day (290 to 310 tons/day), and steam production was about 27,000 kg/h at 4,200 kPa (59,000 lb/h at 610 psig). No additional information on the process was presented in the preliminary letter report.

Emissions are controlled with a WSH/DI/FF system. No description of the air pollution control system was presented in the preliminary letter report.

Particle size distribution at the outlet of the control system was determined during one run by using a Flow Sensor multiclone sampling system. The PM catches from the five cyclones were combined and analyzed for As, Cd, Cr, Ni, and Pb.

3.1.13 Marion County, 1986 Test (Mass Burn, Waterwall)[17]

The Marion County facility in Brooks, Oregon, consists of two, 250-Mg/d (275-ton/d), mass-burn, waterwall combustor units. Solid waste is fed to the Martin GmbH reverse-reciprocating grates by a hydraulically operated ram feeder. The refuse is neither shredded nor sorted prior to incineration. Generally, auxiliary fuel is not fired during normal operation. However, natural gas burners ignite automatically when the flue gas temperature falls below 980°C (1800°F). (This condition may occur during those tests that require the incinerator to operate at reduced waste loads.) Heat is recovered using waterwalls in the furnace and a specially designed boiler system. The steam generated in the boiler is directed to a 13.1-MW turbine-generator to produce electricity. Bottom ash from the combustion grates is quenched before it is combined with the fabric filter ash, dry scrubber cyclone ash, and boiler fly ash. The combined ash is stored in an enclosed residue storage area for final disposal at a landfill.

The air pollution control systems are identical for each of the two units. Each unit is equipped with a Teller-design SD and FF to control acid gas and PM emissions, respectively. The flue gases leave the boiler economizer and enter the bottom of the SD through a cyclonic inlet that removes large particles. Slaked pebble lime is used as a reagent; the lime is mixed with water and injected into the SD through an array of two-fluid nozzles. The stoichiometric ratio of lime to HCl is approximately 2.5. A dry venturi is located immediately before the FF inlet gas plenum. Tesisorb™ material is injected into the dry venturi to enhance collection performance and reduce pressure drop across the FF. The FF has a reverse-air design for cleaning the bags and consists of six compartments. The bag cleaning cycle for each compartment is typically 60 to 75 minutes. After exiting the FF, the combustion gases are discharged through a 78.6-meter- (258-foot-) high stack.

Compliance tests were conducted from September 22, 1986, to October 8, 1986, by Ogden Projects, Inc. The tests were conducted on Units 1 and 2 during normal operation to determine controlled emission levels for: (1) PM by Oregon Department of Environmental Quality Method 5; (2) Pb (Boiler 1 only), Be, and Hg by EPA M12, M104, and M101A, respectively; (3) NO_x and CO by EPA M7E and M10, respectively; (4) SO_2 and HCl by EPA M6C and M5, respectively; (5) PCDD and PCDF (Boiler 1 only) by EPA MM5; (6) chlorides (Boiler 1 only) and fluorides (Boiler 1 only) by EPA M13B; (7) VOC by California Air Resources Board Method 100; and (8) opacity by EPA M9.

3.1.14 McKay Bay, 1986 Tests (Mass Burn, Waterwall)[18-20]

The McKay Bay Refuse to Energy Project consists of four boilers, each controlled by an ESP. Units 1 and 2 are vented through the west stack and Units 3 and 4 through the east stack. Information concerning the operating conditions of the boilers and ESP's is considered confidential by plant personnel.

Tests were conducted in August 1986 using M104 for both sampling and analysis of Be. Emission tests for PM were conducted in September 1986 using M5.

3.1.15 North Andover, 1986 Test (Mass Burn, Waterwall)[21,22]

The North Andover facility, which began operation in 1985, consists of two, identical, mass-burn, waterwall incinerators. Each unit is designed to burn 680 Mg/d (750 tons/d) of municipal waste and produce 90,000 kg/h (198,000 lb/h) of steam at 4,140 kPa (600 psig) and 400°C (750°F). Steam from both boilers drives a 40-MW turbine-generator. Nonprocessed waste is transferred by overhead cranes from a contained pit to gravity-feed hoppers. Hydraulic rams, located at the bottom of the feed hoppers, charge the waste onto Martin reciprocating grates. Underfire and overfire air is drawn from the pit area to fuel the combustion process, which is designed to achieve temperatures in excess of 1370°C (2500°F). Underfire air is supplied through the grates, and overfire air is distributed through nozzles located on the front and rear walls above the flame zone. Each furnace has a volume of 820 m^3 (29,000 ft^3), and each furnace/boiler has 4,900 m^2 (53,000 ft^2) of heat transfer area. Bottom ash is quenched before being combined with the boiler fly ash and ESP ash. The facility is equipped with two CEM systems for CO, CO_2, O_2, NO_x, SO_2, and opacity.

The air pollution control system consists of two, identical ESP's designed to reduce the particulate matter to a level of 115 mg/Nm^3 (0.05 gr/dscf) at 12 percent CO_2, which corresponds to about a 98 percent collection efficiency. Design data for the ESP's are considered confidential by the ESP manufacturer.

The emission measurement program at the North Andover facility was conducted from July 8 to July 16, 1986. Particulate loading was measured according to EPA M5 at the ESP outlet for Runs 1 through 6. During Runs 2, 3, 4, 5, and 6, sampling for PCDD/PCDF at the ESP inlet and outlet was conducted according to the December 1984 draft of the ASME protocol. The PCDD/PCDF sampling was conducted simultaneously at the ESP inlet and ESP outlet. The PCDD/PCDF samples were analyzed by HRGC/HRMS.

As part of an EPA in-house study, trace metals (As, Cd, Cr, and Ni) testing was conducted simultaneously at the ESP inlet and ESP outlet during Runs 7, 8, and 9. Sampling followed EPA Alternative Method 12, which also allows for the concurrent determination of PM emissions. The EPA M12 train has been demonstrated specifically for lead and cadmium only. However, for the purposes of the in-house study, the method was used as a screening analysis for the other metals of interest. The method was also modified by using NAA as the analysis method rather than atomic absorption. The results for arsenic, cadmium, total chromium and nickel were included in the test report.

Continuous emission monitoring for O_2 and CO_2 was also conducted during Runs 7, 8, and 9.

3.1.16 Saugus, 1975 Test (Mass Burn, Waterwall)[23]

The Saugus facility is a mass-burn, waterwall combustor that began commercial operation in 1975. Two parallel process lines each process up to 680 Mg (750 tons) of municipal solid waste per day. The refuse is transferred from the receiving pit to the furnace feed hoppers by overhead cranes. The refuse is neither shredded nor sorted prior to incineration, and auxiliary fuel is not used during normal operation. Heat is recovered using waterwalls in the furnace and an external convection boiler section. Each boiler produces 72,600 kg (160,000 lb) of steam per hour at 4,600 kPa and 450°C (650 psig and 850°F). Each process line includes a two-field ESP for the control of particulate emissions.

Sampling and analysis for PCDD and PCDF were conducted as specified by the ASME draft protocol. The protocol was modified to include the use of a horizontal condenser and the use of methylene chloride for final recovery of PCDD/PCDF. The samples were analyzed by GC/HRMS. Oxygen, CO, and CO_2 were measured by a CEM system at the stack.

3.1.17 Umea, 1984 Test (Mass Burn, Waterwall)[24]

The Umea incinerator is a mass-burn, waterwall design equipped with a boiler. The incinerator is of the cross-grate type and was built in 1970. Raw refuse is charged at a rate of 6 Mg/h (6.6 tons/h). The air pollution control device is an ESP.

Tests were conducted during the fall of 1984 and the spring of 1985 to assess PCDD and PCDF emissions. Measurements were made during both normal and low temperature operations in the fall and during normal operation in the spring. Particulate, condensate, and XAD-2 absorbent tube samples were collected. Analysis was by HRGC/MS. The isomer-specific analysis did not allow the separation of 1,2,3,7,8-PeCDF from 1,2,3,4,8 PeCDF nor 1,2,3,4,7,8-HxCDF from 1,2,3,4,7,9-HxCDF.

3.1.18 Philadelphia, Northwest, 1985 Tests (Mass Burn, Refractory)[25]

The incinerator plant comprises two refuse furnaces, each of which is designed to process up to 340 Mg (375 tons) of trash per day. The units are designed to achieve a 90 percent volume reduction in refuse with a maximum temperature of 1150°C (2100°F). Each furnace consists of a single (primary), excess-air combustion chamber with air-cooled, refractory-lined walls. An elevated crane with a clamshell bucket lifts the refuse from the storage bin into a charging hopper and water-cooled gravity chute. Refuse drops from the chute onto the inclined traveling grate, which continuously feeds the refuse onto a horizontal traveling grate. Each grate is driven by independent, variable-speed motors. The total effective grate area provided by the two grates is 45 m^2 (480 ft^2) per furnace. Combustion air drawn from outside the building is provided to each furnace by an FD fan. The underfire/overfire air ratio is adjusted by dampers in the FD ductwork. Incinerator residues drop off the edge of the horizontal grate and fall through a series of residue quenching sprays and onto a submerged residue conveyor.

The air pollution control system consists of two, two-field ESP's. Furnace flue gases exit through spray chambers where air-atomized water cools the gases to the ESP design operating temperature of between 288° and 316°C (550° and 600°F). The gas streams in the two evaporation towers are subjected to cyclonic flow to remove the largest particles from the flue gases prior to the ESP. Flue gases leave the towers and travel through the precipitator breeching where turning vanes and baffle plates ensure even gas distribution throughout the device. Treated flue gases are drawn from each precipitator by a variable-speed ID fan and exit the plant through a single stack. The ESP fly ash is discharged onto the submerged residue conveyor.

Testing was conducted in 1985 to determine incinerator emissions during normal operation (i.e., furnace temperature between 760° and 980°C [1400° and 1800°F] and indicated inclined grate speed of 70 ft/h). The test protocol included sampling and analyses of ESP fly ash and incinerator bottom ash for PCDD and PCDF; continuous monitoring of stack gas emissions for CO, CO_2, O_2, THC, NO_x, and SO_2; and recording of incinerator and ESP operating parameters. In addition, MM5 was used to determine the PCDD, PCDF, PM, and HCl stack emissions from Unit 1 and Unit 2. One MM5 sample train with a condenser and XAD resin trap was analyzed for PCDD and PCDF by HRGC/HRMS; the other train was analyzed for PM and HCl. Precision and accuracy for the MM5 analysis were assessed by analyzing spiked blanks, determining surrogate recovery results, using National Bureau of Standards (NBS) control samples, and second laboratory analysis.

3.1.19 Washington, D.C., 1976 Test (Mass Burn, Refractory)[26,27]

The Washington Solid Waste Reduction Center No. 1 (SWRC No. 1) incineration facility comprised six, two-chamber, mass-burn, excess-air units. The facility is no longer in operation and has been demolished. The facility had a total capacity of 1,360 Mg/day (1,500 tons/day) and was not equipped with energy recovery equipment. Waste was fed to each furnace by a gravity-feed system. Solid material was moved through the primary chamber on a stoker-grate feed system consisting of four individual sections of continuous-feed grate. Both underfire and overfire air were fed to the primary chamber. Combustion gases left the primary chamber through a cross-over flue and were passed to the secondary chamber.

Emissions from SWRC No. 1 were controlled by a multiple-cyclone collector in series with an ESP. The ESP was a two-field unit with a design efficiency of 95 percent.

Particulate matter samples were collected isokinetically at the scrubber outlet using a modified form of an M5 sampling train. The primary modification was use of an in-stack filter or impactor system. Typical collection time was 30 min. Analyses for most metals were conducted using instrumental NAA. However, some samples were analyzed for Pb and Ni using AA.

3.1.20 Mayport, 1980 Tests (Mass Burn, Refractory)[28,29]

The Mayport Naval Station facility has one, 45-Mg/day (50-ton/day), mass-burn, refractory combustor with a 6,400-kg/h (14,000-lb/h) steam boiler. It is designed to burn municipal refuse and waste oil. The manufacturers of the combustor and boiler are Detroit Stoker Company and Eclipse, respectively. The combustor is designed with primary and secondary chambers, with a bridge wall and air-cooled refractory baffle between the chambers. The primary chamber is equipped with an automatic ram feeder-hopper, an inclined refractory hearth, a water-cooled throat, an oil-fired burner, a stoker grate, and an ash quench tank. Another oil burner is located in the bridge wall-baffle passage. The secondary chamber has refractory lining and enough volume for a 3-s residence time. A steam heat boiler with a surface area of 411 m^2 (4,430 ft^2) is designed to cool the 110-Nm^3/min (4,000-scfm) gas stream from 870° to 260°C (1600°F to 500°F).

The emission control system consists of a 40-tube, multiple-cyclone dust collector.

Tests were conducted in December 1980 to determine PCDD and PCDF emissions while the combustor was burning as-received municipal refuse and waste oil (primarily fuel oil containing unknown contaminants). The unit was operated at a nominal 50 percent capacity level for the 3-day test period. Fuel and ash characteristics and feed rates were determined, and process conditions were monitored. Emission measurements downstream of the cyclone were made for: (1) PM by M5; (2) metals (Cd, Cr, Pb, Ni, et al.) by digesting M5 filter in HNO_3 and analysis by inductively coupled plasma techniques; (3) particle size using a seven-stage MRI Cascade Impactor in-situ; (4) chlorides using H_2O_2 solution in the first impinger of the M5 train; and (5) SO_x and CO with CEM's.[28] Emissions of TCDD and TCDF were determined by MM5 and reported in Reference 28. Sampling was accomplished with a heated filter, cooled XAD-2 sorbent resin trap, and glass-distilled, HPLC-grade water in an impinger. Analyses were performed for 2,3,7,8 TCDD and TCDF isomers and total TCDD and TCDF by GC/HRMS. Packed-column chromatogrophy was used for analysis, identifying TCDD's and TCDF's as either preelutors or coeluters of the 2,3,7,8 isomers. Reported results are presented as "maximum 2,3,7,8" TCDD and TCDF concentrations because of the inclusion of coeluting isomers.

3.1.21 Alexandria, 1976 Test (Mass Burn, Refractory)[26,27]

The Alexandria Municipal Incinerator consists of two, mass-burn, excess-air units with a combined capacity of 270 Mg/day (300 tons/day). The system has a primary and a secondary combustion chamber but does not have energy recovery equipment. Waste is gravity fed to the primary chamber through a charging chute. Solid materials are moved through the chamber by a series of three, inclined, rocking grates. Underfire combustion air is supplied to the primary chamber. Combustion gases from the chamber pass through a flue, where overfire combustion air is added, and into a secondary chamber, where complete combustion is achieved. No data on the distribution of underfire and overfire air are available.

Emissions from the incinerator are controlled by a spray-baffle scrubber. No data on scrubber pressure drop or flows are available.

Particulate matter samples were collected isokinetically at the scrubber outlet using a modified form of an M5 sampling train. The primary modification was use of an in-stack filter or impactor system. Typical collection time was 30 min. Analyses for most metals were conducted using instrumental NAA. However, some samples were analyzed for Pb and Ni using AA.

3.1.22 Nicosia, East Chicago, 1976 Tests (Mass Burn, Refractory)[27,30]

The Nicosia municipal incinerator operated by the City of East Chicago, Indiana, consists of two, identical, mass-burn, excess-air units. Each unit is capable of firing 200 Mg/day (225 tons/day) of unprocessed municipal waste. The system is not equipped with energy recovery equipment. Waste is fed by ram to the combustion chamber and moved through the system on a series of inclined grates. No data are available on combustion airflow to the system.

Atmospheric emissions from each furnace are controlled by a spray chamber followed by a three-stage, horizontal-plate-type scrubbing tower. The liquid/gas ratio of the scrubber is 0.34 ℓ/m^3 (2.5 gal/1,000 acf)

Particulate matter sampling was conducted at the outlet to the scrubber by an M5 train modified to include 1 M HNO_3 in the first two impingers. The filters were analyzed for most metals using instrumental NAA. Analyses for Pb and Ni were performed by AA of the material leached from the filters with HNO_3.

3.1.23 Tsushima, Japan, 1983 Test (Mass Burn, Refractory)[31]

The Tsushima facility consists of two, identical, mass-burn, excess-air incinerators with no energy recovery. Each incinerator has a capacity of 150 Mg/day (165 tons/day). Waste is fed to the system by a ram charging system. A clamshell transfers the waste from the storage pit to the waste charging chute where it is gravity fed to the ram-feed system. A ram feeder pushes the waste onto the furnace grates in a batch process. The waste is transported through the furnace section by inclined, Martin, reverse-reciprocating grates. The combustion air is taken from the waste storage area, preheated, and fired to the furnace as underfire air at a constant rate by an FD fan. No overfire air is used. Combustion gas leaves the chamber at 900°C (1650°F) and is cooled to 450°C (840°F). It then passes through the combustion air preheater where it is cooled to 360°C (680°F) and on to the air pollution control system.

The air pollution control system is a Teller Environmental Systems, Inc., dry scrubbing system. It comprises a cyclone separator, a quench reactor, a dry venturi, and an FF. The combustion gases pass through a cyclone separator and upward through the quench reactor. Nozzles atomize the lime slurry and inject it upwards into the reactor. The lime slurry is 1.5 to 2 percent calcium hydroxide ($Ca(OH)_2$) and is prepared onsite from hydrated lime. The gases pass from the quench reactor to the inlet of the dry venturi where particles (Tesisorb™) are injected with air to reduce bag pressure drop and improve collection and bag pressure drop performance. The exhaust from the venturi is ducted to a reverse-air FF that contains fiberglass bags with silicon-graphite/Teflon™ coating. The FF inlet temperature is about 230°C (440°F), and the air-to-cloth ratio is 0.58 m/min (1.9 ft/min).

The metals testing at Tsushima was conducted as a part of a comprehensive test program to characterize PM, metals, acid gases, and organic emissions from the facility. Metals emission rates were measured at the inlet to the dry venturi on two runs and at the FF inlet on three runs. The samples were collected using a Flow Sensor multiclone apparatus. Metals concentrations were determined for each stage by AA. In addition to the metals tests, PM emissions were determined at the dry venturi inlet, the FF inlet, and the FF outlet using M5. Measurements for Hg emissions were made for two runs each at the quench reactor inlet and FF outlet using M101. Analyses for Hg also were performed by AA.

3.1.24 Pittsfield, 1985 Test-Phase I (Mass Burn, Refractory)[32]

The Pittsfield facility consists of three, 110-Mg/day (120-ton/day), two-stage, refractory-lined incinerators with two waste heat boilers, each with a dedicated EGB precipitator and stack. The facility is designed to operate two units at a time. An overhead crane transfers the waste onto a charging floor from which a front-end loader fills the charging hoppers of the incinerators. Each incinerator has one feed ram and four stoking/ash rams located at various levels along the grates in the primary chamber. Each incinerator has a primary chamber where the refuse is burned, with the hot effluent gases passing into a secondary combustion chamber. Effluent from the secondary chambers passes into a common collection duct that splits off to two waste heat boilers.

Gases from each waste heat boiler pass through an ID fan, into an EGB particulate control device, and to the atmosphere via a stack.

The 1985 tests at Pittsfield consisted of two phases: Phase I to obtain basic information about plant operations and combustion quality over a wide range of test conditions, and Phase II to establish facility parametric relationships among incinerator combustion and operating variables, refuse quality, suspected precursors, and concentrations of various trace compounds including PCDD and PCDF. Only the Phase I results were completed prior to publication of this volume. Comprehensive process monitoring and continuous emission monitoring were performed and recorded on a data logger for subsequent analyses. Three CEM systems were used to measure O_2, CO_2, CO, THC, and NO_x simultaneously at the secondary chamber outlet and at the boiler inlet and outlet locations. Two CEM systems also were equipped to measure SO_2 and H_2O. Sampling by MM5 to measure PCDD, PCDF, and their alleged precursors was conducted simultaneously at the boiler inlet and outlet during two of the test conditions. The two conditions selected were polyvinyl chloride-free material burned at 1010°C (1850°F) and normal refuse burned at 680°C (1250°F) to represent minimum and maximum PCDD/PCDF concentrations, respectively. Chloride analysis was conducted on samples collected at these two test conditions and at two additional conditions. Modified Method 5 sampling and analysis were performed in accordance with the ASME/EPA protocol using an XAD-2 resin cartridge and a condenser. Blank trains, surrogate spiking, and recovery were employed for quality control and quality assurance.

3.1.25 Cattaraugus County, 1984 Test (Starved Air)[33]

The Cattaraugus County Energy Facility, located near the village of Cuba, New York, consists of a tipping floor and three, identical, two-stage, refractory-lined incinerators followed by fire-tube waste heat boilers. Each unit has a maximum capacity of 40 tons of refuse per day. The system has no air pollution control devices. The waste is moved by a skid loader from the tipping floor to the incinerator feed hopper. The refuse is fed by hydraulic ram to the incinerator. The combustion gases discharge through the fire-tube steam boilers to individual 63-foot-high stacks.

The tests were conducted from September 24 to October 26, 1984, by the New York State Region 9 source testing team. The incinerator operated at an average of 94 percent of maximum capacity during the sampling. Concentrations of the following compounds were measured during the normal operation of the plant:

Particulate
2,3,7,8-TCDD
2,3,7,8-TCDF
PCDD (tetra-octa)
PCDF (tetra-octa)
Chrysene
PCB
BaP
Formaldehyde
HCl
Pb
Hg
Manganese

Zinc
Be
Cr
Cd
Ni
Vanadium
As
SO_2
NO_x
CO
CO_2
O_2

Sampling was carried out with EPA-approved or adaptions of EPA-approved methods. In addition, the PCDD/PCDF sampling train was designed by the New York State Department of Environmental Conservation Source Testing Section and is an adaptation of the train proposed by ASME. This MM5 sampling train consisted of a glass-lined probe, a heated glass filter, a cooling condenser, a water-cooled glass cartridge containing 40 grams of XAD-2 resin, and several glass impingers. All sections of the train were glass, connected by Teflon™ unions. The resin was spiked before sampling with a known quality of isotopically labeled 1,2,3,4-TCDD to assess loss or breakthrough of PCDD/PCDF from the resin during sampling. The CDD/PCDF train also was used to sample for the other organics, except formaldehyde. All sampling was carried out at sampling ports on the south stack (Unit No. 1).

3.1.26 Dyersburg, 1982 Tests (Starved Air)[8]

The Dyersburg facility consists of a modular, starved-air incinerator designed to burn 90 Mg/day (100 tons/day) of refuse. The unit was manufactured by Consumat and began operation in 1980. There is no add-on emission control system.

Testing was performed in June 1982 to characterize air emissions during normal operation at an estimated feed rate of 45 Mg/day (50 tons/day) burning approximately 30 percent industrial and 70 percent municipal waste. Detailed data on process operation were not available. Comprehensive emission measurements included: (1) PM by M5; (2) particle size with an Andersen impactor; (3) particle-phase metals from cyclone/filter catch from SASS by XRF (As, Cd, Cr, Hg, Pb, and Ni) and SSMS (Be only); (4) volatile metals (As, Hg, Pb, et al) from SASS impingers with H_2O_2 followed by ammonium persulfate/silver nitrate solutions by AA; (5) HCl and HF by M6 train with NaOH solution in first two impingers by IC; (6) polyaromatic hydrocarbons (BaP, et al.), 2,3,7,8-TCDD/TCDF, total TCDD/TCDF, and PCDD/PCDF with SASS cyclone, filter, and XAD-2 resin catch by HRGC/MS; (7) anions in flyash (sulfate, nitrate, chloride, bromide, fluoride, and phosphate) with SASS impingers with distilled water by IC; and (8) aldehydes (formaldehyde, et al.) with an M6 train with HCl, 2,4-dinitrophenyl-hydrazine, and isooctane in the first two impingers by reverse-phase HPLC. Organic screening analysis to estimate concentrations of various compounds was performed by HRGC/MS from aliquots of the sample extracts, but the reported estimates were not included in the EPA data base.

3.1.27 North Little Rock, 1980 Tests (Starved Air)[28,35]

The North Little Rock facility consists of four, Consumat Model CS-1200, 23-Mg/day (25-ton/day), modular, starved-air incinerators with heat recovery. The facility is contracted to produce an average of 6,800 kg/h (15,000 lb/h) of steam at 150 psi to be delivered 24 hours per day, 5 days per week. Refuse is combusted in two chambers: the primary chamber is designed for 690°C (1200°F) operation for substoichiometric conditions; the secondary chamber is designed for 1000°C (1825°F) operation through control of primary and secondary air. Two rams in the primary chamber hearth are cycled to push residue and break up clinker formations. A drag chain removes the wetted ash for disposal. Combustion gas is cooled to 380°C (600°F) after it passes through the boiler, which is equipped with five banks of vertical water tubes. There is no add-on emission control system.

The tests were conducted in March, May, and October 1978. Particulate matter and heavy metals in particulate form were captured by the filter of an EPA MM5 train. Heavy metal vapors and other gases were captured by the impingers in an EPA M5, M7, or M8 train. Particulate matter was captured for size distribution analysis by a seven-stage, vertical cascade impactor. The concentrations of O_2, CO, CO_2, NO_x, and sulfur oxides were monitored continuously.

3.1.28 Prince Edward Island, 1985 Test (Starved Air)[34]

The Prince Edward Island facility uses two-stage, starved-air combustion of municipal solid waste in combination with waste heat recovery. The plant comprises three, two-stage, Consumat CS 1600 modular incinerators, each rated at 33 Mg/d (36 tons/d), with a common exhaust manifold leading to a single waste heat boiler and economizer and an exhaust fan and stacks. Waste is fed to the primary chamber in a batch mode and is moved through the primary chamber by a sequence of water-cooled hydraulic rams. Low-velocity combustion air enters the lower portion of the bed in the primary chamber. Combustion gases leave the primary chamber through a short breeching at the front end of the secondary chamber. In the secondary chamber, these gases are mixed with preheated secondary combustion air, and combustion is completed. The combustion gases leave the secondary chamber through the waste heat boiler and economizer. During the testing, only the gases from incinerator unit No. 1 were passed through the waste heat boiler. The facility has no add-on air pollution control system.

The metals testing at Prince Edward Island was conducted during the second phase of the test program--the performance test phase. During the performance tests, three replicate runs were conducted at each of four test conditions--normal operation, long feed cycle, high secondary chamber temperature, and low secondary chamber temperature. The selection of test conditions was based on the results of 22 characterization tests conducted during the first phase. These results indicated that the major variables that affected operations were secondary chamber temperature, primary chamber airflow rate, and refuse loading rate. The normal operation test was selected as a baseline for comparison. During the long cycle tests, the number of feed cycles was reduced from 8 per hour to 6 per hour with an increase in mass fired per charge to maintain a constant mass feed rate. This condition was expected to improve combustion and reduce demands on the loader operator. The high and low secondary temperature conditions were achieved by increasing the secondary chamber temperature set point by 135°C (240°F) and decreasing it by 100°C (180°F) from normal condition, respectively. The high and low temperature conditions were selected because the secondary chamber temperatures appeared to have a significant impact on organic emissions.

The measurement scheme for each test was complex with a wide variety of waste, process, and flue gas parameters monitored during each run. The waste feeds were monitored for metals, and stack gases were monitored for both PM and gas-phase metals. A sampling train similar to an M5 with five impingers was used. The first two impingers contained 5 percent aqua regia, and the third impinger contained 2 percent $KMnO_4$ in 10 percent H_2SO_4 for metals collection. Metals analyses generally were conducted with a direct-coupled plasma analyzer. Mercury was analyzed by AA.

Organic pollutants measured at Prince Edward Island included homolog-specific analyses of PCDD and PCDF, PCB, total polycyclic aromatic hydrocarbons, chlorophenol, and chlorobenzene. The organic sampling train was an MM5 train modified as specified by the ASME draft protocol for PCDD/PCDF. Quantitation of all organics was by gas chromatography/mass spectroscopy-multiple ion detection (GC/MS-MID).

Acid gas emissions were measured by using a glass-lined probe and a series of impingers containing caustic solutions. Single-point sampling was used. Impinger solutions were analyzed by IC. Pollutants that were measured were HCl, HF, and SO_3.

A continuous emission monitoring train was used to measure stack gas concentrations of CO, CO_2, SO_2, NO_x, and THC.

3.1.29 Tuscaloosa, 1985 Test (Starved Air)[37]

The Tuscaloosa Energy Recovery incinerator facility consists of four, modular, starved-air municipal refuse incinerators manufactured by Consumat Systems and installed in 1984. Each incinerator has a rated capacity of 80 Mg/d (90 tons/d) and typically operates 24 hours per day, 5 days per week. Exhaust from the four incinerators is fed through two heat recovery boilers to produce 24,900 kg (55,000 lb) of steam per hour. Approximately 99 percent of the refuse incinerated is from residential sources, and the remaining 1 percent consists of scrap tires. Temperature in the primary chamber of each incinerator is maintained between 540° and 760°C (1000° and 1400°F). Secondary chamber temperatures typically are 1150°C (2100°F).

Particulate matter emissions are controlled by an ESP manufactured by Precipitair Pollution Control. Exhaust from the four incinerators is routed through the ESP prior to exiting through a single stack. An ID fan is located after the ESP and before the stack.

All tests were conducted while the four incinerator modules were operating normally at approximately 90 percent of capacity. Lower and upper chamber temperatures were monitored and controlled to operate in the typical ranges of 530° to 650°C (980° to 1200°F) and 1130° to 1160°C (2080° to 2120°F), respectively. Controlled emission results were not considered representative because (1) ESP power levels were not steady and were substantially less than the design level and (2) excessive air inleakage at the ID fan flange occurred throughout most of the test period. Uncontrolled and controlled emission testing included PM by M5, NO_x by M7, inorganic As by M108, Cr^{+6} by digesting M5 filters in an alkaline solution with analysis by the diphenylcarbazide colorimetric method, and particle sizing with an Andersen Mark III impactor and an Andersen heavy grain loading impactor/cyclone.

3.1.30 Barron County, 1985 Test (Starved Air)[38]

The Barron County waste-to-energy facility consists of two Consumat Model No. CS-1600 incinerators. Each incinerator has a rated capacity of 45 Mg/d (50 tons/d) and is equipped with a heat recovery boiler featuring an economizer. The boilers have a nominal steam output of 4,500 kg/h (10,000 lb/h) at 4,100 kPa (600 psi) each. Secondary chamber temperatures are maintained above 820°C (1500°F).

Emissions are controlled by a two-chamber, two-stage ESP.

During the test, the incinerators were firing about 79 Mg/d (87 tons/d), the boilers were producing about 7,700 kg/h (17,000 lb/h) of steam at 3,400 kPa (500 psi), and the ESP's first and second stages were energized at 38 kV and 28 kV, respectively. Controlled emission testing was by EPA M5 for PM. The M5 filters and probe washes were analyzed by AA for Pb, Cr, Ni, As, and Cd. The impinger portion of the M5 train was analyzed for HCl with a specific ion probe.

3.1.31 Red Wing, 1986 Test (Starved Air)[39-42]

The Red Wing MSW incinerator is a twin-unit facility manufactured by Consumat Systems. The total capacity of 65 Mg/d (72 tons/d) from the two incinerators produces an average solid waste heating value of 10,500 kJ/kg (4,500 Btu/lb). The combined incinerator flue gases heat one steam boiler that has a nominal steam output of 8,000 kg/h (17,700 lb/h) at 1,100 kPa (150 psig). The bottom ash and ESP ash are combined in the conveyor and transported to a landfill.

Particulate matter emissions are controlled by an ESP. Exhaust from the two incinerators is routed through the ESP prior to exiting through a single stack. No ESP design data were provided in the test report.

Controlled emission testing included PM and trace metals by EPA M5; PCDD and PCDF by MM5; HCl by caustic impinger; Hg by $kMnO_4$ impingers and gold amalgamation; and CO, CO_2, O_2, SO_2, and NO_x by CEM. Analysis included PM by EPA M5, trace metals by ICAPS, PCDD and PCDF by GCIMS, HCl by EPA 325.2, Hg by cold vapor AAS, CO and CO_2 by NDIR, O_2 by paramagnetic analyzer, SO_2 by pulse fluorescence, and NO_x by chemilumiscence.

3.1.32 Akron, 1981 Test (RDF Fired)[8]

The Akron facility is designed to burn 910 Mg/day (1,000 tons/day) of RDF in a semisuspension, stoker-grate combustor. Processing of RDF includes shredding, air classification, and magnetic separation. Emission control is provided by an ESP. No other information on the process or the control system was included in the report.

Testing was performed in May 1981 to characterize MWC stack emissions during normal operation at an estimated feed rate of 550 Mg/day (600 tons/day). Comprehensive emission measurements included: (1) PM by M5; (2) particle size with an Andersen impactor; (3) particle-phase metals from cyclone/filter catch from SASS by XRF (As, Cd, Cr, Hg, Pb, and Ni) and SSMS (Be only); (4) volatile metals (As, Hg, Pb, et al.) from SASS impingers with H_2O_2 followed by ammonium persulfate/silver nitrate solutions by AA; (5) HCl and HF by M6 train with NaOH solution in first two impingers by IC; (6) polyaromatic hydrocarbons (BaP, et al.), 2,3,7,8-TCDD/TCDF, total TCDD/TCDF, and PCDD/PCDF with SASS cyclone, filter, and XAD-2 resin catch by HRGC/MS; (7) anions in flyash (sulfate, nitrate, chloride, bromide, flouride, and phosphate) with SASS impingers with distilled water by IC; and (8) aldehydes (formaldehyde, et al.) with M6 train with HCl, 2,4-dinitrophenyl-hydrazine, and isooctane in first two impingers by reverse-phase HPLC. Organic screening analysis to estimate concentrations of various compounds was performed by HRGC/MS from aliquots of the sample extracts, but the reported estimates were not included in the EPA data base.

3.1.33 Albany, 1984 Test (RDF Fired)[43]

The Albany facility consists of two, identical, 276-Mg/day (300-ton/day) combustors and 45,000-kg/h (100,000-lb/h) steam generators. The RDF feed to the plant has been mechanically processed offsite. Waste processing includes air and magnetic separation of noncombustible material followed by shredding to facilitate combustion. The RDF feed is moved to the incinerator by screw conveyors and fed to the combustion chambers by two air-blast distributors. The incinerator is a single-chamber, waterwall unit with a traveling grate stoker for ash agitation and movement. The heat recovery system includes superheater tubes, a convection bank, an economizer, and a combustion air preheater.

Particulate matter emissions from the combustion chambers are controlled by two, identical ESP's. Each ESP has a conventional wire-to-plate design with three separately energized fields in the direction of gas flow. Both precipitators discharge into a single stack. Difficulties with the plate rapping systems were experienced during the test period.

The metals testing at Albany was conducted as a part of extensive testing of air emissions from the facility. Three replicate runs were conducted at each of two replicate test conditions--one with RDF and natural gas and one with RDF only as fuel. Particulate matter sampling was conducted at the ESP inlet on Unit 8 and at the stack (the combined exhaust from Units 7 and 8). The inlet sampling was conducted with an M5 train. The train at the stack was modified by adding 100 ml of 3 M HNO_3 in the first two impingers for collection of Cd, Cr, Pb, and Ni. Sampling at the stack was also conducted for Hg using EPA Method 101A, for As using M108, and for Be using EPA M104. Analyses for the metals in the M5 train were conducted by AA. Other analyses were: Hg--AA, As--cold vapor AA, and Be--AA.

Organic pollutants measured at the Albany RDF plant were PCDD and PCDF (including the 2,3,7,8-tetra isomers), BaP, chrysene, PCB, and formaldehyde. Sampling for PCDD and PCDF was conducted using an MM5 train similar to the train specified in the ASME draft protocol. Teflon™ connectors were used to eliminate grease problems. Analyses were conducted by GC/MS using the New York Department of Health Protocol. The same type of train was used for sampling BaP, chrysene, and PCB. Sampling for formaldehyde was performed with an M6 train modified by using sodium bisulfite in the midget impingers. Analysis was by colorimetry.

Hydrochloric acid was collected by placing 100 ml of 0.1 N NaOH in each of the first two impingers of the particulate train. The chloride concentration in the impinger catch was determined by specific ion electrode (SIE).

A continuous emission monitoring system was used to determine stack gas concentrations of O_2 (electrochemical cell) and CO and CO_2 (NDIR). Limited continuous monitor data also were presented for NO_x (M7) and SO_2 (methodology was not described).

3.1.34 Hamilton-Wentworth, Ontario, 1984 Tests (RDF Fired)[44,45]

The Hamilton-Wentworth facility consists of two, identical, 272-Mg/day (299-ton/day) combustors and 48,200-kg/h (106,000-lb/h) steam generators. Municipal waste is mechanically processed onsite and fed into two Babcock and Wilcox Canada Limited spreader-stoker boilers. Waste processing includes shredding, magnetic separation, and transport on conveyors before the waste is pneumatically spread into the boiler through the overfire air ports. Overfire air is supplied through nozzles located along the upper and lower rear walls, along the front wall below the feed chutes, and through slots in the feed chutes. Underfire air is supplied separately through holes in the traveling grates. Bottom ash is discharged by the grates into a water quench hopper and trucked to a landfill. Combustion gas is cooled by the steam boiler and combustion air preheater to about 310°C (590°F).

The PM emissions from each unit are controlled by a two-field Wheelabrator Frye ESP. Both precipitators discharge emissions through separate ID fans and oval flues contained in one circular stack.

The purpose of testing was to examine the effect of MWC operational variables on PCDD/PCDF emissions. The test program was divided into four field tasks: a pretest program, a cold flow study, combustion runs, and diagnostic tests. The pretest program and cold flow study were preliminary in nature. The combustion runs were made to measure boiler parameters and PCDD/PCDF emissions under different operating conditions in order to select conditions for the diagnostic tests. These tests were conducted with various combinations of overfire air ports. Two tests were run without overfire air port use for each load condition (F/None and H/None). One test was conducted under full load with the lower back overfire air port in use (F/Low back) while two tests were conducted under half-load conditions (H/Low back). Under full load, four tests were conducted with both back air ports in use (F/Back), and two tests were conducted with both back and lower front overfire air ports in use (F/Back, low front). These tests were not repeated under half-load conditions. Each diagnostic test has been averaged separately and included in the EPA data base. All the diagnostic tests were conducted on Unit 1.

The methodology for trace organic emission sampling included an MM5 train equipped with two adsorbent traps containing Florisil located between the third and fourth impingers, nickel-plated nozzles, glass probes, and Teflon™ seals throughout the train. Sample recovery/extraction procedures included sample probe, nozzle, and all glassware rinses with pentane followed by rinses with methylene chloride. Analyses for PCDD/PCDF were performed using data from HRGC/MS analyses. Analysis for ClB's, ClP's, and PCB was by GC using dual capillary column separation with dual ECD. Continuous emission monitors were used to measure CO, CO_2, O_2, SO_2, NO_X, and THC.

3.1.35 Niagara, 1985 Test (RDF Fired)[46]

The RDF facility located in Niagara Falls, New York, is operated by the Occidental Chemical Corporation and has two combustors rated at a total of 1,100 Mg/day (1,200 tons/day). The plant consists of a tipping floor, bulk storage building, shredders, metal separators, two identical furnaces with 25-MW steam turbine generators, and ESP's. The refuse is moved from the storage building to the shredders by hydraulic rams and a conveyor. The shredded refuse is conveyed to the ferrous metals separation operation by conveyor. After the ferrous metals are removed, the RDF is fed to the furnaces through surge bins. The fuel is introduced to the furnaces using air-swept distributors in front of each furnace.

Particulate matter emissions at the facility are controlled by ESP's.

Sampling at the plant was conducted during May and June 1985 while Unit 1 operated normally at 75 to 90 percent of the maximum steam load. No process or ESP operating parameters were included in the preliminary test report. Concentrations of the following compounds were measured during the tests:

PM
PCDD
PCDF
Chrysene
PCB
BaP
Formaldehyde
HCl
Pb
Hg
Manganese
Zinc
Be
Cr
Cd
Ni
Vanadium
As
SO_2
NO_x
CO
CO_2
O_2

Sampling was carried out with EPA-approved or adaptions of EPA/ASME-approved methods. The PCDD/PCDF sampling train consisted of a glass-lined probe, a heated glass-fiber filter, a cooling condenser, a water-cooled glass cartridge containing 40 g of XAD-2 resin, and several glass impingers. All sections of the train were glass and were connected by Teflon™ unions. The resin was spiked before sampling with a known quantity of isotopically labeled 1,2,3,4-TCDD to determine sample retention efficiency. The same train was also used to sample for the other organics.

3.1.36 Wright Patterson Air Force Base, 1980 and 1982 Tests (RDF Fired)[7,28]

The Wright Patterson facility has an 11,000-MJ/h (100×10^6-Btu/h), spreader-stoker, waterwall boiler (Detroit Rotograte Stoker Boiler), which is designed to burn coal for steam production and plant heating. Fuel is gravity fed through a bin and chute and mechanically spread into the combustion chamber. Combustion air is preheated by the exhaust gas through a heat exchanger. The facility operators were investigating the possibility of switching from coal to RDF for fuel.

The emission control system consists of a multiclone cyclone followed by an ESP.

Tests were conducted in April 1980 to assess PCDD and PCDF emissions from refuse burning resource recovery facilities.[28] The unit was operated at a 2.1-Mg/h (2.3-ton/h) feed rate (nominal 30 percent capacity level) burning densified RDF for 1 day. Fuel and ash characteristics and feed rates were determined, and process conditions were monitored. Controlled PM and organic emissions were determined by MM5. Sampling was accomplished with a heated filter, cooled XAD-2 sorbent resin trap, and glass-distilled, HPLC-grade water in an impinger. Analyses were for 2,3,7,8 isomers and total TCDD and TCDF by HRMS/GC. Packed-column chromotography was used for analysis, identifying TCDD's and TCDF's as either preelutors or coeluters of the 2,3,7,8 isomers. Reported results are presented as "maximum 2,3,7,8" TCDD and TCDF concentrations because of the inclusion of coeluting isomers.

Tests were also conducted in June 1982 to evaluate measurement methods for sampling chlorinated hydrocarbons, gaseous HCl, and particulate chloride.[7] The unit was operated at a feed rate of 8.5 Mg/h (9.4 tons/h) and burned RDF during the test period. During the night, the unit was cofired with coal to conserve the RDF. Process conditions were not reported. Organic compounds were sampled using an MM5 train with glass beads in the first two impingers and an XAD-2 sorbent resin (60 g) cartridge located between the third and fourth impingers. Organic compound analysis was performed with HRGC/HRMS to measure (1) tetra- through octa-PCDD and PCDF homologs; (2) di- through hexa-ClB homologs; (3) tri- through penta-ClP homologs; and (4) tri- through hexa-PCB.

Measurements for HCl were by an M6 train with NaOH in all four impingers and also by an M5 train with NaOH in the first two impingers. Analysis for HCl was by the mercuric nitrate method modified by treating the sample with H_2O_2.

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4. DISCUSSION OF FUTURE DATA AVAILABILITY

The growing concerns about the risks associated with projected construction of new MWC facilities have resulted in an increased number of ongoing and planned emission test programs that will expand data availability. Consequently, the emission data base will continue to be in a state of flux. The emission data base represents the core of information on emissions that will be used to support regulatory analyses and decisions. As new data are received, they directly impact sufficiency of the data base for:

1. Development of emission factors and risk assessments;
2. Control technology assessments;
3. Identification of issues related to emissions, control costs, risks, etc.; and
4. Identification of regulatory alternatives and development of rationale in support of specific alternatives.

New data will be generated by several different groups. Because added data are needed to make regulatory decisions, EPA is identifying recently conducted tests for which reports are under development and is planning additional test programs over the next 2 years. Additional data are expected to be collected by State regulatory agencies, Environment Canada, and MWC vendors. For example, two tests (i.e., North Andover, Massachusetts, and Marion County, Oregon) have been conducted recently through the joint efforts of facility owners/operators, State regulatory agencies, and EPA.

Table 4-1 presents details of the facilities and emission data from tests that have been completed recently or that are being planned. The footnotes in Table 4-1 include information on the anticipated report schedules for each of the tests. These dates are based on information

TABLE 4-1. SUMMARY OF FUTURE DATA AVAILABILITY[a]

	Starved air			Excess air					RDF				
		ESP			ESP		Dry scrubber			ESP		Dry scrubber	
Pollutant	Uncontrolled emissions	Controlled emissions	Efficiency	Uncontrolled emissions	Controlled emissions	Efficiency	Controlled emissions	Efficiency	Uncontrolled emissions	Controlled emissions	Efficiency	Controlled emissions	Efficiency
Criteria Pollutants													
Part.	OS	OS,OH	OS	O,W	G[b],W,PC,Q	W	O,F	O	R	H		R	R
SO_2	OS	OS,OH	OS	O,W	G[b],W,PC,Q	W	O,F	O	R			R	R
NO_x	OS	OS,OH	OS	O,W,PC	W,PC,Q	W,PC	O	O	R			R	R
CO	OS	OS,OH	OS	W,O	W,PC,Q	W	O,F	O	R			R	R
THC (volatile)	OS	OS,OH	OS	W	W,Q	W							
Toxic Metals													
As	OS	OS,OH	OS	O,W	W,PC,Q	W	O	O	R			R	R
Be	OS	OS,OH	OS	W	W,Q	W			R			R	R
Cd	OS	OS,OH	OS	O,W	W,PC,Q	W	O	O	R			R	R
Cr	OS	OS,OH	OS	O,W	W,PC,Q	W	O	O	R			R	R
Pb	OS	OS,OH	OS	O,W	W,PC,Q	W	O	O	R			R	R
Hg	OS	OS,OH	OS	O,W	W,PC,Q	W	O	O	R			R	R
Ni	OS	OS,OH	OS	W	W,PC,Q	W			R			R	R
Acid Gases													
HCl	OS	OS,OH	OS	O,W	W,Q	W	O,F	O	R			R	R
HF													
H_2SO_4 or SO_3^-													

(continued)

TABLE 4-1. (continued)

	Starved air			Excess air					RDF				
		ESP			ESP		Dry scrubber			ESP		Dry scrubber	
Pollutant	Uncontrolled emissions	Controlled emissions	Efficiency	Uncontrolled emissions	Controlled emissions	Efficiency	Controlled emissions	Efficiency	Uncontrolled emissions	Controlled emissions	Efficiency	Controlled emissions	Efficiency
Organics													
TCDD	OS	OS,ON	OS	W,O,PC	G^b,W,PC,Q	W,PC	O,F	O	R	H		R	R
TCDF	OS	OS,ON	OS	W,O,PC	G^b,W,PC,Q	W,PC	O,F	O	R	H		R	R
PCDD	OS	OS,ON	OS	W,O,PC	W,PC,Q	W,PC	O,F	O	R	H		R	R
PCDF	OS	OS,ON	OS	W,O,PC	W,PC,Q	W,PC	O,F	O	R	H		R	R
Precursors	OS	OS,ON	OS	W,O,PC	W,PC,Q	W,PC	O	O	R			R	R

[a] O = Marion County, Oregon; first U.S. state-of-the-art excess-air MWC with dry scrubber; EPA parametric test planned for summer and fall 1987; results available in early 1988.
W = Westchester/Peekskill, New York; preliminary report in hand; final report availability uncertain.
G = Galax, Virginia, compliance test on rotary MWC with baghouse; report available in summer 1987.
H = Haverhill, Massachusetts; final report available in summer 1987.
OS = Oswego, New York; preliminary report in hand; final report availability uncertain.
ON = Oneida, New York; preliminary report in hand; final report availability uncertain.
PC = Pinellas County, Florida; tests conducted in February 1987; draft report available in June 1987.
R = RDF parametric test planned for spring 1988 at a state-of-the-art facility yet to be determined; sponsored by EPA and Environment Canada; results available in late 1988.
F = Framingham, Massachusetts, compliance test; testing to occur in July 1987; draft data available in late 1987.
Q = Quebec City parametric tests; final report available in July 1987.

[b] Notation that site characteristics do not meet conventional requirements for category.

provided by EPA, State agencies, Environment Canada, and MWC vendors. It should be noted that although many of the test reports referenced on Table 4-1 were identified as becoming available in early 1987, none of those listed have yet been received.

5. SAMPLING AND ANALYSIS PROTOCOL

The purpose of this chapter is to provide a brief description of the sampling and analysis (S&A) methodologies that were used to generate the emission data presented in Chapter 7. Because S&A methods were not the same for all tests, a direct comparison of the data from different tests is difficult. This chapter is designed to illustrate the variety of S&A methods associated with the emission test data and to facilitate an evaluation of the comparative quality and accuracy of those data. The S&A methodologies for each test are identified and described in Tables 5-1 and 5-2. Table 5-1 summarizes the S&A methodologies for the criteria pollutants, acid gases, and organics. Table 5-2 summarizes the methodologies for the metals. Acronyms and abbreviations are listed in Supplement B. Additional information on recommended S&A methodologies is contained in another volume of this comprehensive report entitled Municipal Waste Combustion Study: Sampling and Analysis of Municipal Waste Combustors (EPA/530-SW-87-021F).

The S&A methodologies used in the tests to measure the criteria pollutants are more uniform than those used for other categories because EPA reference methods for criteria pollutants are well defined, and those methods generally were used for the reported test programs. The detailed test procedures for EPA reference methods are found in 40 CFR, Part 60, Appendix A. Only two facilities of those listed in Table 5-1 used a non-EPA test method for determining PM emissions. The test conducted at Malmo utilized a quartz FF, and the test conducted at Hamilton-Wentworth utilized an isojet sampler with a tared filter bag for the collection of the PM. The other facilities were tested using the standard EPA M5, sometimes with minor modifications as indicated. Tests were conducted at 22 facilities using M5, at 4 facilities using M5 in combination with M8, and at 1 facility using M5, M8, and M17.

At most test sites, CO levels were monitored continuously, in most cases using NDIR. The actual method was unspecified at several sites. The testing methodology for SO_2 levels reported at 19 sites included EPA Method 5, 6, 8, or 13, and combinations of these, as noted in Table 5-1. Four sites also reported continuous monitoring of SO_2 using ultraviolet detection methods. The test report for Kure also indicated that SO_2 was verified by the Chronoamperometric Detection Method, and the report for Mayport indicated that SO_2 and NO_x were measured by electrochemical detection methods. In six tests, NO_x levels were measured continuously using the chemilumenescence method, and in two tests, M7E was utilized. Method 7 was used at the Tuscaloosa and Albany tests. Nitrogen oxide levels were measured continuously at three other sites for which the reports did not describe the test methods.

Test methods for THC were more varied. Four tests used GC/FID for continuous monitoring, while three tests utilized FID. At three other test sites, California Air Resources Board Method 100, charcoal tubes and metal gas bombs, and absorption tubes containing Tenax™ GC were used. In the last two cases, analysis was by GC/FID. At four test sites, the testing methodology was not described.

Acid gases (HCl, HF, and H_2SO_4) were all tested by a variety of S&A methods. For several tests, EPA Method 5, 6, 8, 13A, or 17 and combinations of these were used. The S&A methodologies and modifications used are described in Table 5-1.

The same general S&A procedures were used for the organics tests. Sampling was isokinetic; a filter was used to capture particle-phase organics, and some type of resin was used to absorb the gas-phase organics. The ASME draft protocol for dioxins or some other modification of the EPA M5 train typically was used, and analysis was performed by GC/MS.[1] The S&A methodology for testing organics is evolving. In the past, Florisil and Tenax™ had been used as the sorbents for collecting semivolatile and nonvolatile organics. The ASME draft protocol for semivolatile and nonvolatile organics established in December 1984 standardized both S&A procedures using an MM5 train and XAD-2 resin as the sorbent. The actual test reports should be consulted for information about specific differences in the S&A protocols at different sites.

In general, the same S&A protocol was used to test for all the metals at a given site. However, in some tests a different S&A methodology was used for some of the metals, especially for those metals for which EPA test methods are specified. At the Tulsa test, M12 and M104, modified by combining the probe rinse and impinger liquid, were used to test for Be and Pb, and M101A was used to test for Hg. The test at Albany also used M108 to test for As; M101 or M101A was used to test for Hg at the Gallatin and Tsushima facilities.

Several facilities also were tested using identical S&A protocols. The metals tests at Gallatin, Munich, Wurzburg, and Tsushima were all performed using a Flow Sensor sampling system with analysis by AA, except where different methods for Hg are noted. The tests at Washington, D.C.; Alexandria; and Nicosia also followed the same S&A methodology (MM5 train with analysis by instrumental neutron activation [INA]). The tests at Hampton (1982), Dyersburg, and Akron were all performed by analyzing the SASS train particulate and volatile metals catch by XRF and SSMS.

In 14 of the tests, an M5 or MM5 sampling train was used. Modifications of the M5 train included using an in-stack filter (Washington, D.C.; Alexandria; and Nicosia), using aqua regia in the first two impingers and $KMnO_4$ in H_2SO_4 in the third impinger (Prince Edward Island), and using nitric acid in the first two impingers (Albany). The test at Braintree used both M5 and SASS trains. Four tests (three performed by Copper Engineering, Inc.) used Flow Sensor multiclone sampling systems, and two facilities (Tulsa and Malmo) used other methodologies as noted in Table 5-2.

In addition to the variations in S&A methodologies among the tests, different metal phases also were measured. The majority of the metals tests analyzed the particle phase (i.e., that captured on a filter). Five facilities (Braintree, Prince Edward Island, Dyersburg, Akron, and Hampton, 1982) were tested for metals in both the particle phase and the condensible phase (i.e., absorbed in resin traps or impingers). The test report for Malmo indicates that only the condensible metals were tested. In addition, some tests also specifically sampled for Hg in the vapor phase.

Analysis techniques for the various metals also varied widely. Most analyses were performed using AA, although other methods included SSMS, INA, direct coupled plasma, and XRF. Table 5-2 provides details on the various S&A methodologies.

TABLE 5-1. SAMPLING AND ANALYSIS METHODOLOGY SUMMARY--CRITERIA POLLUTANTS, ACID GASES, AND ORGANICS

		Criteria pollutants					Acid gases			
Facility (Test date)	Sampling[a]	PM	CO	SO_2	NO_x	THC	HCl	HF	H_2SO_4	Organics[b]
Mass burn/waterwall										
Baltimore (1/85)	Outlet	M5[c]	M10[d]	M8[e]	M7[f]					
Baltimore (5/85)	Inlet and outlet[g]	M5								
Braintree (1978)	Outlet	M5	NDIR[h]	NDIR	i	FID[j]				
Chicago Northwest (1980)	Inlet and outlet		k			l				MM5[m]
Hampton (1981)	Outlet	M5					M6[n]			MM5[o]
Hampton (1982)	Outlet	M5/SASS				M25[p]	M6[q]	M6[q]		SASS[r]
Hampton (1983)	Outlet		k			k				MM5[s]
Hampton (1984)	Outlet	M5	k							MM5[o]
McKay Bay	Outlet	M5	M10	M6[t]	M7					
North Andover	Inlet and outlet	M5	M10							MM5[u]
Peekskill (1985)[v]	Outlet	M5[w]								MM5[x]
Saugus	Outlet		k							MM5[u]
Tulsa (1986)	Outlet	M5	NDIR	M8/13[y]	M7E[z]	CM100[aa]	M8/13A[bb]	M8/13A	M8/13A	MM5[cc]
Umea	Outlet									dd
Gallatin (1983)[ee]	Inlet	M5/8[ff]	NDIR	M5/8-UV[gg]	i	GC/FID[hh]	M6[ii]	M6[ii]	M5/8	
Kure (1981)[ee]	Inlet and outlet	M5/8[jj]	NDIR	M5/8 or 6-UV[kk]	i	ll	mm	nn	M6/8	
Munich (1984)[ee]	Inlet and outlet	M5/8		M5/8			M6[ii]		M5/8	
Malmo (1983)[oo]	Inlet and outlet	FF[pp]	k			qq	rr			
Quebec (1985)	Inlet and outlet[ss]	M5[tt]	NDIR[uu]	UV		FID[vv]	ww			MM5[xx]
Wurzburg (1985)[ee]	Outlet	M5/8	NDIR	M6[k]	i	FID	M6[k]			yy
Marion County (1986)	Outlet	M5[tt]	M10	M6C	M7E[z]	CM100[aa]	M5			MM5
Mass burn/refractory										
Philadelphia (1985)	Outlet	MM5	k	k	k	k	M5[zz]			MM5[†a]
Washington, D.C. (1976)	None									
Mayport (1980)	Outlet	M5	NDIR			GC/FID	M5[†b]			MM5[†c]
Alexandria (1976)	None									
Nicosia (1986)	None									
Tsushima (1983)	Inlet and outlet	M5/8/17		M5/8	†d		M5/17	M5/17		
Pittsfield (1985)	Inlet					GC/FID				MM5[†e]
Starved air										
Cattaraugus County	No control device									†f
Dyersburg (1982)	No control device	M5/SASS					M6[q]	M6[q]		SASS[r]
N. Little Rock (1980)	No control device	MM5	k	k	k					
Prince Edward Island (1985)	No control device	M5[†g]	NDIR	UV	i	GC/FID	†h	†h		†i
Barron County	Outlet	M5	NDIR				M5[†j]			
Red Wing	Outlet	M5	NDIR	UV	i		M5[†k]			MM5[†l]
Tuscaloosa (1985)	Inlet and outlet	M5			M7[†m]					
RDF-fired										
Akron (1981)	Outlet	M5/SASS					M6[q]	M6[q]		SASS[r]
Albany (1984)	Inlet and outlet[†n]	M5	NDIR	k	M7[k]		M5[†o]			MM5[†p]

(continued)

TABLE 5-1. (continued)

Facility (Test date)	Sampling[a]	Criteria pollutants					Acid gases			Organics[b]
		PM	CO	SO_2	NO_x	THC	HCl	HF	H_2SO_4	
Hamilton-Wentworth (1984)	Outlet	†q	NDIR	k		tr				†s
Niagara (1985)[v]	Outlet	ND[tt]		ND	ND		ND			
Wright Pat. AFB (1980)	Outlet									MM5†c
Wright Pat. AFB (1982)	Outlet						M6[p] †u			MM5[d]

Acronyms and abbreviations are listed in Supplement B.

[a] Inlet means samples taken after the combustor and before the control device. Outlet means samples taken after the control device.

[b] Includes polycyclic and chlorinated hydrocarbons, PCDD, PCDF, and other organic compounds.

[c] EPA M5 for PM.

[d] EPA M10, continuous monitoring with NDIR.

[e] EPA M8 for sulfur dioxide.

[f] EPA M7 for nitrogen oxides.

[g] Inlet and outlet testing for PM only. Front and back half of trains analyzed.

[h] Continuous in-stack monitoring with NDIR.

[i] Continuous in-stack monitoring with chemiluminescence.

[j] Monitoring by FID.

[k] Continuous in-stack monitoring.

[l] Continuous in-stack monitoring for C_1-C_6 hydrocarbons.

[m] Organics sampled by MM5. Analysis for PCDD, PAH's, PCB, PCDF and total chlorinated organics by HRGC, HRGC/MS, HRGC/Hall electrolytic conductivity and FID, or HRGC/SIM.

[n] Outlet sampling by using M6 with four midget impingers each containing NaOH. Analysis by the mercuric nitrate method modified by treating sample with H_2O_2. Nonisokinetic.

[o] Outlet organic compounds sampled using MM5 train with glass beads in the first two impingers and an XAD-2 resin cartridge between the third and fourth impingers, extraction by methanol, and analysis by HRGC/HRMS.

[p] EPA M25 equipment quantitated by FID and ECD.

[q] EPA M6 train with NaOH solution in first two impingers, analysis by IC.

[r] Modified by replacing stainless steel module used to collect semivolatile organic compounds with glass. Following the condenser was a glass trap containing XAD-2 resin. Particulate material collected in cyclones followed by quartz fiber filter. Extraction of volatile components using methylene chloride. Analysis by HRGC/MS and HRGC/HRMS.

[s] The modification consisted of a condenser to cool the gases and XAD-2 resin cartridge placed between the filter box and the first impinger. Analysis by HRGC/MS, HRGC/MS-SIM, and HRGC/HRMS-SIM.

[t] EPA M6 for acid gases.

[u] MM5 sampling train with XAD-2 resin cartridge after filter and before impingers. Specified by EPA/ASME environmental/standards workshop.

[v] Sampling using EPA-approved or adaptations of EPA-approved methods.

[w] Particulate data may be invalid because PM in the test ports may have fallen and become part of the sample.

[x] PCDD sampling train designed by adapting the ASME train. Train consisted of fiber filter, condenser, XAD-2 resin cartridge, and several glass impingers.

[y] EPA M8 and M13.

[z] EPA M7E for nitrogen oxides.

[aa] California Air Resources Board M100.

[bb] EPA M8 and M13A. Modified by not using glass filter.

[cc] Trace chlorinated organics by MM5.

[dd] Sampling train collected samples from filter, condensate, and XAD-2 resin. Analysis by HRGC/MS.

[ee] Testing performed by Cooper.

[ff] EPA M5 or M5 combined with M8.

[gg] Continuous in-stack monitoring with UV.

[hh] Continuous in-stack monitoring by GC/FID.

[ii] EPA M6 modified by using distilled water in impingers.

[jj] The condensable portion of the particulate also was analyzed.

[kk] Continuous in-stack monitoring verified by Chronoamperometric Detection Method and electroconductivity.

[ll] THC sampled by charcoal tubes and light hydrocarbons sampled by metal gas bombs. Analysis using GC/FID.

TABLE 5-1. (continued)

[mm] Separate sampling train. Analysis by $AgNO_3$ (instead of mercuric nitrate) which measures total halogens instead of HCl only.

[nn] Separate sampling train. Analysis by SIE.

[oo] Also RDF fired.

[pp] Isokinetic extraction and collection on quartz filter fabric at 320°F.

[qq] Hydrocarbons C_6-C_{18} by adsorption tubes containing Tenax™ GC. Analysis by GC/FID and capillary column.

[rr] Sample from two impingers in series with NaOH. Analysis by filtration with $AgNO_3$ using ion selective electrode.

[ss] Testing performed before the scrubber, between the scrubber and the fabric filter, and after the fabric filter.

[tt] Oregon DEQ Method 5.

[uu] NDIR continuous monitoring outlet only.

[vv] At inlet and outlet only.

[ww] One sample train consists of two midget impingers containing water. M5 train with a series of water and aqua regia impingers. Analysis by IC. Continuous monitoring with gas filter correlation.

[xx] Gaseous organics trapped in XAD-2 resin tube and an ethylene glycol-filled impinger. Analysis by GC/MS.

[yy] EPA VOST method for volatile organics with analysis by GC/MS. Other organic sampling performed by ASME draft protocol with XAD resin cartridge and filter analyzed by GC/MS-SIM.

[zz] The first three impingers of this train were analyzed by the colorimetric, ferricyanide method, EPA Method 325.3

[†a] Sampling by M5 train modified with XAD resin catridge and condenser prior to impingers containing water, KOH, and silica gel. Extraction with hexane and methylene chloride, analysis by HRGC/MS-SIM.

[†b] M5 sample train modified to include H_2O_2 in first impinger. Anaylsis by EPA M325.3.

[†c] Trace organics collected with M5 sample train, modified to include XAD-2 resin trap. Sample extracted with methanol and methylene chloride, and analyzed by GC/MS.

[†d] Continuous monitoring using a Fuji electric monitor which is not approved for CEM use in the U.S. because it is based on infrared absorption, not chemiluminescence.

[†e] MM5 sampling and analysis in accordance with ASME/EPA protocol using XAD-2 resin cartridge and a condenser.

[†f] Sampling train designed by the New York State Department of Environmental Conservation. It is an adaptation of the train proposed by the ASME.

[†g] Similar to M5 train. First two impingers contain 5 percent aqua regia; third impinger contains 2 percent $KMnO_4$ in 10 percent H_2SO_4.

[†h] Glass-lined probe and series of standard-size impingers (instead of specified midget size) containing NaOH solution. Single point sampling; analysis by IC.

[†i] MM5 train as specified by ASME draft protocol. Analysis by GC/MS-MID.

[†j] The impinger portion of the M5 sampling train for chlorides was analyzed with a specific ion probe.

[†k] M5 sampling train with 0.1 N NaOH in impingers. Analysis using EPA M325.2 (colormetric, automated ferricyanide) using a Technicon AAII

[†l] MM5 sampling train as recommended by the October 1984 ASME/Argonne Environmental Standards workshop. The XAD-2 resin trap is placed between the filter and impingers. Analysis by GC/MS.

[†m] EPA M7 performed at outlet.

[†n] PM sampling at inlet and outlet; all other sampling at stack outlet only.

[†o] EPA M5 train modified to include NaOH in first two impingers. Analysis by SIE.

[†p] Sampling by MM5 train similar to the train specified in the ASME protocol. Extraction by acetone and hexane, analysis by GC/MS.

[†q] Isojet sampler using tared filter bag.

[†r] Continuous monitoring by FID.

[†s] M5 train modified to contain two Florisil tubes after the impingers. Analysis by HRGC/MS and capillary column GC with ECD.

[†t] Test method not described.

[†u] Also used a MM5 by using NaOH in first two impingers instead of water to compare sampling methods. Analysis by SIE. Nonisokinetic.

TABLE 5-2. SAMPLING AND ANALYSIS METHODOLOGY SUMMARY--METALS

Facility (Test date)	Sampling[a]	Metals						
		As	Be	Cd	Cr	Pb	Hg	Ni
Mass burn/waterwall								
Baltimore (1/85)	None							
Baltimore (5/85)	Inlet and outlet	M108[b]			M5[c]			
Braintree (1978)	Inlet and outlet	M5/SASS[d]	M5[e]	M5/SASS[f]	M5/SASS[g]	M5/SASS[f]	M5/SASS[h]	
Chicago Northwest (1980)	Outlet			M5[i]				
Hampton (1981)	None							
Hampton (1982)	Outlet	SASS[j k]	SASS[l]	SASS[m]	SASS[m]	SASS[j n]	SASS[j o]	SASS[m]
Hampton (1983)	None							
Hampton (1984)	None							
McKay Bay	Outlet		M104[p q]			M12[q]	M101A[r q]	
North Andover	Inlet and outlet	M12[s]		M12[s]	M12[s]			M12[s]
Peekskill (1985)	None							
Saugus	None							
Tulsa (1986)	Outlet		M12/104[t]			M12	M101A	
Umea	None							
Gallatin (1983)[u]	Inlet	v	v	v	v	v	M101[w]	v
Kure (1981)	Inlet and outlet[aa]	M5[x]		M5[x]	M5[x]	M5[x]	y	M5[x]
Munich (1984)[u]	Outlet	v	v	v	v	v		v
Malmo (1983)	Inlet and outlet			z		z	aa	
Quebec (1985)	Inlet and outlet[bb]	M5[cc]	M5[dd]	M5[dd]	M5[dd]	M5[dd]	ee	M5[dd]
Wurzburg (1985)[u]	Outlet	v		v	v	v		v
Marion County (1986)	Outlet		M104			M12	M101A	
Mass burn/refractory								
Philadelphia (1985)	None							
Washington, D.C. (1976)	Outlet	MM5[ff]		MM5[gg]	MM5[ff]	MM5[hh]		MM5[hh]
Mayport (1980)	None							
Alexandria (1976)	Outlet	MM5[ff]		MM5[gg]	MM5[ff]	MM5[hh]		MM5[hh]
Nicosia (1976)	Outlet	MM5[ii]		MM5[jj]	MM5[ii]	MM5[kk]		MM5[kk]
Tsushima (1983)	Inlet and outlet[ll]	v	v	v	v	v	M101	v
Pittsfield (1985)	None							
Starved air								
Cattaraugus County	None							
Dyersburg (1982)	No control device	SASS[j k]	SASS[l]	SASS[m]	SASS[m]	SASS[j n]	SASS[j o]	SASS[m]
N. Little Rock (1980)	No control device		MM5	MM5	MM5	MM5		MM5
Prince Edward Island (1985)	No control device	MM5[mm]		MM5[mm]	MM5[mm]	MM5[mm]	MM5[mm]	MM5[mm]
Barron County	Outlet	M5[q]		M5[q]	M5[q]	M5[q]		M5[q]
Red Wing	Outlet	M5[nn]	M5[nn]	M5[nn]	M5[nn]	M5[nn]	M5[oo]	M5[nn]
Tuscaloosa (1985)	Inlet and outlet	M108			M5[pp]			
RDF-fired								
Akron (1981)	Outlet	SASS[j k]		SASS[m]	SASS[m]	SASS[j n]	SASS[j o]	SASS[m]
Albany (1984)	Outlet	M108[qq]	M104	M5[rr]	M5[rr]	M5[rr]	M101A[q]	M5[rr]
Hamilton-Wentworth (1984)	None							
Niagara (1985)[ss]	Outlet	ND[tt]	ND	ND	ND	ND	ND	ND
Wright Pat. AFB (1980)	None							
Wright Pat. AFB (1982)	None							

(continued)

TABLE 5-2. (continued)

Acronyms and abbreviations are listed in Supplement B.

[a] Inlet means samples taken after the combustor and before the control device. Outlet means samples taken after the control device.

[b] EPA M108 for As.

[c] Hexavalent chromium measured by placing M5 filters in an alkaline solution and analysis by the diphenylcarbazide colorimetric method. Total Cr determined by NAA.

[d] Vaporous As measured by hydride generation AA method from SASS outlet train. M5 particulate filters analyzed by SSMS/hydride AA.

[e] M5 filters analyzed by SSMS.

[f] Measured by AA with air-acetylene flame and SSMS.

[g] M5 filters analyzed by SSMS and SASS outlet train analyzed by AA.

[h] Special sampling train at outlet for Hg vapor; KOH solution in first impinger; second and third impingers contained acidic $KMnO_4$; the fourth impinger was dry; and fifth contained silica gel. Vapor Hg from special train and SASS outlet train measured by cold vapor generation AA method. Particulate catches from M5 and SASS train measured by SMSS and cold vapor AA.

[i] Samples from M5 digested with aqua regia and acid solutions. Analysis by AA with air-acetylene flame.

[j] Volatile trace elements trapped in the liquid impinger train which contains H_2O_2 in the first impinger and ammonium persulfate/$AgNO_3$ in the following two impingers.

[k] Volatile phase analysis by hydride generation techniques. SASS cyclone/filter catch analysis by XRF.

[l] Analysis by SSMS.

[m] SASS cyclone/filter catch analyzed by XRF.

[n] Analysis using graphite furnace and XRF

[o] Analysis using flameless, UV technique; EPA M245.1 (manual cold vpor technique).

[p] EPA M104 for Be.

[q] Analysis using AA.

[r] EPA M101A for Hg.

[s] Alternate EPA M12. The outlet train contained 100 ml of 0.1 N HNO_3 in the first three impingers. The fourth impinger was empty and the fifth contained silica gel. Particulate collected from the nozzle was not included in the metals analysis. Analysis by NAA.

[t] EPA M12 for Pb and M104 for Be. Modified by combining probe rinse and impinger liquid.

[u] Testing performed by Cooper.

[v] Flow Sensor multiclone sampling system. Analysis by AA.

[w] EPA M101 for Hg. Analysis using AA.

[x] The metals analyzed at the outlet were not identified. Samples from M5 filters analyzed by NAA. Different particulate size ranges analyzed by emission spectrophotometry.

[y] Hg sampled at inlet only. Two EPA methods (not identified) used to measure Hg.

[z] Samples from two impingers containing HNO_3. Analysis by AA.

[aa] Samples from three impingers with separate solutions of NaOH and $KMnO_4$ with H_2SO_4. Analysis by AA.

[bb] Testing performed before the scrubber, between the scrubber and the FF, and after the FF.

[cc] Analysis by FAA.

[dd] Analysis by DCPES.

[ee] Hg scrubbed by two impingers containing $KMnO_4$. Recovery of Hg in the particulate form by washing front-half components with dichromate and immersing the filter in this solution. Recovery of impingers involved the reduction with hydroxylamine hydrochloride followed by a dichromate solution. Analysis by FAA.

[ff] M5 modified by use of in-stack filter. Analysis by NAA.

[gg] M5 modified by use of in-stack filter. Analysis by both NAA and AA.

[hh] M5 modified by use of in-stack filter. Analysis by AA or materials leached from filters with HCl and/or HNO_3.

[ii] Glass fiber filters analyzed by NAA.

[jj] Glass fiber filters analyzed by both NAA and AA.

[kk] Glass fiber filters analyzed by AA.

[ll] Hg sampled at both inlet and outlet. Other heavy metals only sampled at inlet.

[mm] Sample train similar to that of M5. First two impingers contained 5 percent aqua regia, third impinger contained 2 percent $KMnO_4$ in 10 percent H_2SO_4. Analysis generally by DCPES. Mercury is analyzed by AA.

[nn] M5 modified using 10 percent nitric acid in the first two impingers. Analysis by ICAPS.

[oo] M5 modified using 200 ml of 5 percent $KMnO_4$ in 1 N HNO_3 in the first two impingers. Analysis by cold vapor AA. Mercury was also sampled using a gold amalgamation technique. Analysis by thermally desorbing the mercury from the gold followed by a cold vapor AA technique.

[pp] Cr collected on EPA M5 filter, digested in an alkaline solution with analysis by the diphenylcarbazide colorimetric method for Cr^{+6}.

[qq] Analysis by cold vapor AA.

[rr] Collected in an M5 train modified to include HNO_3 acid in first two impingers, analyzed by AA.

[ss] Sampling using EPA-approved or adaptations of EPA-approved methods.

[tt] Test methods not described.

REFERENCE FOR CHAPTER 5

1. PEI Associates, Inc. Emission Test Report--Baltimore RESCO Incinerator, Baltimore, Maryland. Prepared for U. S. Environmental Protection Agency, Emissions Measurements Branch, Research Triangle Park, North Carolina. July 1985. (Draft--Pending Determination and Final Metals Analyses).

6. PROTOCOL FOR DATA BASE

6.1 ENGINEERING METHODOLOGY

A thorough review of 36 test reports from U.S. and foreign MWC's was performed to establish a data base for four classes of pollutants: criteria pollutants, acid gases, metals, and organic compounds. Data log forms were created to document and facilitate transfer of reported emission and process information to pollutant-specific data base files created using dBase III®, a data base management software package, on an IBM-compatible personal computer (PC). A PC program was written to perform most of the calculations and present the results in a consistent and comparable format. Pollutant-specific tables were generated by the computer to (1) list results for uncontrolled and controlled emission levels and collection efficiency, (2) present emission results in a concentration format (pollutant mass per unit volume) and as an emission factor (EF) in pollutant mass per mass of waste feed, (3) identify the treated facility by name and type, and (4) present separate tables for standard international (SI) and English units. The sections below briefly describe the methodology and rationale used to develop the data base files and programs.

The emission data documented on the data log forms (example forms are included as Supplement C) were averaged as the arithmetic mean of different sampling runs prior to inclusion in the PC data base. Test programs at most facilities consisted of three to six sampling runs conducted during distinct operating conditions; groups of runs at the distinct conditions were treated as separate tests. Separate results from multiple test programs or test conditions were reported for the following facilities: Hamilton-Wentworth, Hampton, Malmo, McKay Bay, Philadelphia, Prince Edward Island, Quebec, Umea, and WPAFB. Tests at the Hamilton-Wentworth MWC were performed and reported for six different operating conditions based on load and air distributions. Tests conducted four different times in as many years were reported individually for the Hampton MWC. Distinct tests at Malmo were performed while firing normal refuse and RDF and reported separately. At McKay Bay, tests were conducted and results reported on Unit 1, Unit 2, Unit 3, and Unit 4. Tests were conducted and results reported on Unit 1 and Unit 2 at the Philadelphia Northwest MWC. The comprehensive tests at Prince Edward Island were conducted during four distinct and controlled operating conditions: normal operation, long feed cycle operation, high secondary chamber temperature, and low secondary chamber temperature. Tests at the Quebec MWC were performed and reported for four different conditions using a slipstream controlled by a pilot-scale WSH/DI/FF and two different conditions using a slipstream controlled by pilot-scale SD/FF. Tests conducted during the fall of 1984 and spring of 1985 at the Umea MWC were reported individually. At WPAFB, tests were conducted on two occasions and reported separately.

Due to the variety of formats used to report units of measure at different MWC facilities, the emission data required some preprocessing to standardize the units of measure prior to computer calculation of emission concentration levels and EF's. Particulate and metals data reported in 10 different units were manually converted to mg/dscm or gr/dscf and corrected to 12 percent CO_2. The results were used to calculate EF's in units of μg/Mg and lb/ton and emissions of metals as particulate fractions in units of pollutant mass per particulate mass. Computerized preprocessing was possible with the data bases for acid gases, criteria pollutants, and organic compounds because the variety of measurement units was limited. The list of conversion factors used in the data base preprocessing is included as Table 6-1.

In the acid gases and criteria pollutants data bases, some preprocessing required simple calculations in addition to unit conversions. If the pollutant-specific data, D1, were reported in ng/dscm corrected to 12 percent CO_2 in the test report, the following calculation

$$DI=D1x(\text{percent concentration of } CO_2)/12$$

was performed in the preprocessing portion of the PC program ACALC to

TABLE 6-1. LIST OF CONVERSION FACTORS

Multiply	By	To obtain
mg/Nm^3[a]	4.37×10^{-4}	gr/dscf[b]
m^2	10.764	ft^2
m^3/min	35.31	ft^3/min
m/s	3.281	ft/s
kg/h	2.205	lb/h
kPa	4.0	in. of H_2O
lpm	0.264	gal/min
kg/Mg	2.0	lb/ton

Temperature conversion equations

°F=(9/5)*°C+32

°C=(5/9)*(°F-32)

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[a] Normal conditions on a dry basis are 1 atm and 20°C.
[b] Dry standard conditions are 1 atm and 68°F.

present the "uncorrected" value in the resulting table. When the data, D1, were reported in ng/dscf in the test report, the conversion

$$D1=D1x35.31$$

was required to present D1 as ng/dscm. Acid gas and criteria pollutant data were presented in ppmdv corrected to 12 percent CO_2. In order to convert data, D1, from mg/dscm corrected to 12 percent CO_2 to ppmdv at 12 percent CO_2, the relation

$$D1=D1x(1000x0.02404)/(\text{molecular weight of pollutant})$$

was employed.

Calculation of EF's was performed using conversion factors (CF's) to relate process conditions to emission concentration levels. The CF's were calculated manually for each facility that provided percent concentration of CO_2, process feed rate, and stack gas flow measurements. The EF's in 10^{-10} lb/ton were calculated using the "corrected" concentration data in English units, E1 in 10^{-10} gr/dscf, and the following equation

$$EF=CFxE1$$

where

$$CF=\frac{(\text{Percent concentration of } CO_2)(\text{stack gas flow in dscfm})(7.14x10^{-4})}{\text{Process rate in ton/h}}.$$

The EF's in µg/Mg were then calculated using

$$\text{EF in } \mu g/Mg=(\text{EF in } 10^{-10} \text{ lb/ton})x0.05$$

In order to calculate EF's from data presented in ppmdv at 12 percent CO_2, a second conversion factor, CCF, was needed. CCF was defined as

$$CCF=\frac{(\text{molecular weight of pollutant})(1.3x10^{-8})(CF)}{(7.14x10^{-4})}.$$

An EF value may be calculated from

$$\text{EF in lb/ton feed}=(\text{D1 in ppmdv @ 12 percent } CO_2)(CCF).$$

Because test periods were nonsimultaneous, CF values for some facilities were different for the various pollutants. Table 6-2 presents the values for CF, CO_2, stack gas flow rate, and process feed rate that were used in the data base for emission calculations. Determinations of EF's were made only when process feed rates were documented or derivable from plant records of refuse process rates and steam flow rates. Discrepancies (±15 percent) in EF calculations can result from interpretation of process conditions during sampling periods and data averaging techniques. To reduce these potential discrepencies, EF values were taken directly from the test report whenever possible.

Quality control and quality assurance procedures were used to assure that the data base accurately reflected the reported test data. Each data log form was checked by a second person to assure documentation of reported emission and process data prior to development of the computer data base. The data log forms provided the structure for the PC data base files and quality check. After emission tables were generated, a final comparison was made between randomly selected test reports, their associated data log form, and the produced emission table to assure the quality of the data acquisition and the associated calculations.

6.2 COMPUTER PROGRAMMING METHODOLOGY

The dBase III® programs initially were modified and titled in a pollutant-specific fashion; these gradually were developed into a more generalized format to allow for improved quality control and consistant data manipulation. The programs were written in a modular fashion with a main procedure, MAINRPT, calling several subroutines. These subroutines were designed to (1) conduct the preprocessing, correction to 12 percent CO_2, emission percentage, and EF calculations; (2) print the table heading and column identifications; (3) print the facility type, name, control device type, and test condition; and (4) print the emission data and calculation results.

The data base files remained pollutant-specific to check test reports known to have measured these pollutants. These files are presented in Table 6-3. These data files were used in their associated computer programs to generate the pollutant-specific tables as shown in

TABLE 6-2. SUMMARY OF DATA USED TO CALCULATE EMISSION FACTORS

Facility name	Test condition	Organic data				All other pollutants			
		CO_2, %	SFR, dscfm	PR, ton/h	CF	CO_2, %	SFR, dscfm	PR, ton/h	CF
Mass burn									
Waterwall									
ESP									
Baltimore	Normal	11.3	110,000	27.0	21.7	17.0	110,000	27.0	21.7
Braintree	Normal	4.20	20,900	4.96	12.5	4.20	20,900	4.96	12.5
Chicago	Normal	8.97	52,300	19.1	17.5	9.10	53,200	19.1	18.9
Hampton (1981)	Normal	6.60	18,800	5.11	17.4	6.60	18,800	5.11	17.4
Hampton (1982)	Normal	12.1	12,800	5.20	21.2			5.20	21.2
Hampton (1983)	Normal	12.9	12,700	5.20	22.4	12.9	12,700	5.20	
Hampton (1984)	Normal	6.70	10,100	13.8	3.52	6.70	10,100	13.8	3.52
Peekskill (4/85)	Normal	7.90				7.90			
Tulsa (Unit 1)	Normal	9.80	40,200	15.6	8.0	9.80		15.6	18.0
Tulsa (Unit 2)	Normal	9.40	45,300	15.6	19.5	9.40		15.6	19.5
CYC/FF									
Gallatin	Normal	10.5	13,100	3.83	25.6	10.5	13,100	3.83	25.6
ESP/WS									
Kure	Normal	6.90	17,200	6.25	13.6	6.90	17,200	6.25	13.6
CYC/DI/ESP/FF									
Malmo	Normal	11.3	34,000	10.5	26.2	11.3	34,000	10.5	26.2
WSH/DI/FF									
Quebec	110	7.10	2,490	10.4	1.21			10.4	1.21
Quebec	125	7.40	2,560	10.4	1.29			10.4	1.29
Quebec	140	7.50	2,450	10.4	1.26			10.4	1.26
Quebec	200	7.30	2,120	10.4	1.06			10.4	1.06
Marion County	Normal					8.39	36,577		
Wurzburg	Normal	7.70	30,600	12.3	13.6	7.60	30,600	12.3	13.5
SD/FF									
Quebec	140	8.30	2,480	10.4	1.41			10.4	1.41
Quebec	140 & R.	7.50	2,410	10.4	1.24			10.4	1.24
Refractory									
ESP									
Philadelphia (NW1)	Normal	5.3	75,600			5.30	77,200		
Philadelphia (NW2)	Normal	4.7	85,100			4.70	83,800		
CYC/ESP									
Washington, D.C.	Normal								
CYC									
Mayport	MSW/Waste oil	7.7	8,380	1.03	44.7	7.70	8,380	1.03	44.7

(continued)

TABLE 6-2. (continued)

Facility name	Test condition	Organic data				All other pollutants			
		CO_2, %	SFR, dscfm	PR, ton/h	CF	CO_2, %	SFR, dscfm	PR, ton/h	CF
WS									
Alexandria	Normal								
Nicosia	Normal								
SD/FF									
Tsushima	Normal	6.20	17,800	6.24	12.6	6.20	17,800	6.24	12.6
EGB									
Pittsfield	Experimental			7.10				7.10	
Starved air									
None									
Cattaraugus County	Normal								
Dyersburg	Normal	7.03	8,160	2.08	19.4	7.00	8,160	2.08	19.4
Prince Edward Island	Normal	8.00	5,960	1.75	19.3	8.00	5,960	1.76	19.3
Prince Edward Island	Long	8.00	5,710	1.76	18.5	8.00	5,710	1.76	18.5
Prince Edward Island	High	11.1	4,640	1.87	19.7	11.1	4,640	1.87	19.7
Prince Edward Island	Low	7.00	6,860	1.68	20.5	7.00	6,860	1.67	20.5
ESP									
Tuscaloosa	Normal	7.00	44,900	13.6	16.5	7.00	44,900	13.6	16.5
RDF fired									
ESP									
Akron	Normal	8.10	48,900	25.0	11.3			25.0	1.3
Albany	Normal	9.50	78,500	23.6	22.6	9.50	77,400	23.6	22.2
Hamilton-Wentworth	Normal	9.70				9.70			
Hamilton-Wentworth	Half load	6.40				6.40			
Niagara	Normal		143,000					41.3	
CYC/ESP									
Wright Pat. AFB	Normal	7.60	48,800	9.38	28.3	7.60	48,800	9.38	28.3
Wright Pat. AFB	Dense RDF								
CYC/DI/ESP/FF									
Malmo	RDF	11.5	39,300	10.5	30.7	11.5	39,300	10.5	30.7

TABLE 6-3. DATA FILES

Name	Contents
DATAEMIS	Particulate and metals emissions
DATACID	Acid gas data
COSO2	Criteria pollutant data
NEWORG	Organic data: total measured penta's, hexa's hepta's, octa's, benzene, benzo-a-pyrene, chlorinated phenols, and chlorinated benzenes
DATAORG	Organic data: 2,3,7,8-tetra's, total tetra's, and tetra- through octa's
ORGSITE	Facility type, name, control device, test condition, and reference number
TOTFAC	Percent CO_2 concentration, stack gas flow, process rate, and CF
COTAB	Collection efficiency, temperatures, and flow rates
ESP	ESP design and operating conditions data
DSFF	DS and FF design and operating conditions data

Table 6-4. These programs required simple modifications prior to producing desired tables. These modifications included selecting desired table number, desired data type, and altering the field name used in the program to reflect this data type.

TABLE 6-4. SUMMARY OF PROGRAMS

Name	Input data file	Tables produced
PARTIC	DATAEMIS	Particulate
METALS	DATAEMIS	Metals
ACID	DATACID	Acid gases
ACID	COSO2	Criteria pollutants
ORGNEW	NEWORG	Total penta's, hexa's, hepta's, and octa's
ORG	DATAORG	2,3,7,8-tetra's, total tetra's, and tetra-through octa's
TOTALD	NEWORG	Total measured PCDD
TOTALF	NEWORG	Total measured PCDF
BEN	NEWORG	Benzo-a-pyrene, total chlorinated benzene and phenol, and benzene
CONTAB	ESP	ESP design specifications
CONTAB1	DSFF	DS/FF design specifications
CONTAB2	DSFF	FF or scrubber design specifications
CONTAB3	ESP	ESP operating conditions
CONTAB4	DSFF	DS/FF operating conditions
CONTAB5	DSFF	FF or scrubber operating conditions

7. DATA BASE

7.1 DISCUSSION OF PROCESS AND CONTROL DEVICE TABLES

7.1.1 Discussion of Process Design and Operation Tables

Design and operating information for the process equipment in use at the 30 test sites is presented in tabular format in this section. Specific design factors anticipated to have causal relationships with combustion efficiency and/or pollutant emission levels have been identified in the combustor design tables. A paucity of performance-related design information is available in the emission test reports identified in Supplement A. Tables 7-1a and 7-1b present the available structural and airflow design specifications, respectively, for the mass-burn facilities in SI units. Process operating conditions are presented in Table 7-2 for the mass-burn facilities in SI units. Comparable design data for the starved-air facilities and RDF facilities are presented similarly in Tables 7-3a, 7-3b, 7-5a, and 7-5b. Process operating conditions are presented for starved-air and RDF-fired facilities in SI units in Tables 7-4 and 7-6, respectively. The same table sequence is followed for process design and operating conditions in English units for Tables 7-59 through 7-64.

7.1.2 Discussion of Control Device Design and Operating Condition Tables

Control device design and operating characteristics are presented in Tables 7-7 through 7-12 in SI units, and Tables 7-65 through 7-70 in English units. Tables 7-7 and 7-65 present ESP design data in SI and English units, respectively. Comparable design data for the DS systems are presented in Tables 7-8 and 7-66. Tables 7-9 and 7-67 present design data for WS and FF systems in SI and English units, respectively. Operating conditions are presented for the different types of control equipment in the same sequence in Tables 7-8, 7-10, and 7-12 in SI units, and in Tables 7-68 through 7-70 in English units.

7.2 DISCUSSION OF EMISSION TABLES

The emission test data for the 36 test sites examined during this study are presented for 48 specific pollutants or related pollutants in Tables 7-13 through 7-58 and Tables 7-71 through 7-116. Each table presents emission data for one pollutant/related pollutants either in SI units or in English units. Data are presented in SI units in Tables 7-13 through 7-58 and in English units in Tables 7-71 through 7-116. For each test site, the tables present the type of facility, facility name, type of control device, test condition, and three columns of emission values for uncontrolled and controlled emission levels upstream from and downstream from the control device. For most tables, emission values are presented in units of mass/stack gas volume in dry standard conditions (DSC) of 20°C and 760 mm Hg (68°F and 29.92 in. Hg), in DSC converted to 12 percent CO_2, and mass of pollutant per mass of feed input.

For the metals tables, emission values are presented in units of mass of metal emissions/mass of PM emissions in lieu of mass/stack gas volume at DSC. The four classes of pollutants are presented in the following sequence of tables: (1) the four criteria pollutants are presented in Tables 7-13 through 7-16 in SI units and Tables 7-71 through 7-74 in English units; (2) the 7 metals are presented in Tables 7-17 through 7-23 in SI units and in Tables 7-75 through 7-81 in English units; (3) the 3 acid gases are presented in Tables 7-24 through 7-26 in SI units and Tables 7-82 through 7-84 in English units; and (4) the 21 organic pollutants or related pollutants are presented in Tables 7-27 through 7-55 in SI units and Tables 7-85 through 7-113 in English units.

The supplementary emission data from 27 test sites for PCDD, PCDF, and metals are presented in Tables 7-56 through 7-58, respectively, in SI units and Tables 7-114 through 7-116 in English units.

It should be noted that the "emissions upstream from control device" and "emissions downstream from control device" designations on the tables in this chapter are indicative only of the location at which the measurements were made. These designations were selected to present the emission data in a consistent format that permits comparison. Control efficiencies are presented for those control devices known to demonstrate control over a specific pollutant. In some cases, these designations could result in negative control efficiencies for some gas-phase pollutants like SO_2, NO_x, and CO. However, the lack of control of such pollutants is not a reflection of the efficiency of the PM control device. Rather, variations in the measured values of such pollutants upstream and downstream of the PM control device typically are a product of the normal variation expected with any test method (and are suitably footnoted as they occur in the tables).

Facility type/structural and airflow design data/operating conditions in SI units

7-1a Mass-Burn Facility Structural Design Data
7-1b Mass-Burn Facility Airflow Design Data
7-2 Mass-Burn Operating Data for MWC Facilities
7-3a Starved-Air Facility Structural Design Data
7-3b Starved-Air Facility Airflow Design Data
7-4 Starved-Air Operating Data for MWC Facilities
7-5a RDF-Fired Facility Structural Design Data
7-5b RDF-Fired Facility Airflow Design Data
7-6 RDF-Fired Operating Data for MWC Facilities

TABLE 7-1a. MASS-BURN FACILITY STRUCTURAL DESIGN DATA

Facility	Chamber configuration				Heat transfer area		Grate data			
	Primary chamber		Secondary chamber							
	Geometric configuration	Volume, m^3	Geometric configuration	Volume, m^3	Convective, m^2	Total, m^2	Manufacturer	No. of sections	Pressure drop, kPa	Capacity, Mg/d
Baltimore					83		a			686
Braintree					1,840		b			109
Chicago							c			363
Gallatin							e			91
Hampton							d	3		114
Kure							e			
Peekskill							a			680
N. Andover	Rectangular	820			4,710	4,960	c			680
Quebec							a	3		227
Tulsa							c			340
Munich										740[f]
Wurzburg							c			
Tsushima							c			150
Malmo							c			218
Saugus								3		680
Marion County										250
Umea										
Philadelphia										340

[a] Von Roll.
[b] Riley Stoker.
[c] Martin.
[d] Detroit Stoker.
[e] O'Connor water-cooled rotary combustor.
[f] 480 Mg/d of MWS and 260 Mg/d of clarified sludge.

TABLE 7-1b. MASS-BURN FACILITY AIRFLOW DESIGN DATA

	Underfire air							Overfire air				
				Flow distribution, percent						Nozzle data		
Facility	No. of plenums	No. of controlled flows	Flow rate, m^3/min	Feed	Dry	Combustion	Burnout	Location	Flow direction	Number	Type	Velocity, m/s
Quebec	5				0	70	30			20		
N. Andover								Front wall Backwall	Horizontal Inclined	30 31	2.75 in. dia. 2.75 in. dia.	

TABLE 7-2. MASS BURN OPERATING DATA FOR MUNICIPAL WASTE COMBUSTOR FACILITIES

Facility name	Feed rate, % design	Temperatures			Flow rate, Nm^3/min	Stack gas concentrations				
		Furnace, °C	Boiler outlet, °C	Stack, °C		O_2, %	CO_2, %	H_2O, %	CO, ppm	THC, ppm
Mass burn										
Waterwall										
ESP										
Baltimore, 5/85	85		321	228	3,100	11.5	7.50	12.1		
Braintree				198	592	16.1	4.20	6.3	474	11.3
Chicago		627		238	1,480	11.4	8.97		163	
Hampton (1981)	98			275	533	13.5	6.60			
Hampton (1982)				270	362	7.70	12.1			
Hampton (1983)		804		271	260	6.40	12.9		1,130	55.7
Hampton (1984)	86	816		360	287	11.9	6.70		136	
N. Andover				307		10.4	9.4	13.4	32.1	
Peekskill (4/85)	95-112						7.90			
Saugus						10.5	10.1		30.6	
Tulsa (Unit 1)					1,140		9.80			
Tulsa (Unit 2)					1,280		9.40			
Umea, fall, normal		804								
Umea, fall, low temp		538								
Umea, spring		782								
CYC/FF										
Gallatin				173	370	9.40	10.5			348
ESP/WS										
Kure				221	407	14.6	6.9			
SD/ESP										
Munich				159	2,150	12.5	7.2	17.4		
CYC/DI/ESP/FF										
Malmo		816	290	963	7.50	11.3				
WSH/DI/FF										
Quebec, 110					70.5	12.7	7.10			
Quebec, 125					72.5	12.4	7.40			
Quebec, 140					69.5	12.5	7.50			
Quebec, 200					60.0	12.9	7.30			
Wurzburg		904		185	866	10.7	7.6	15.5	41	
SD/FF										
Marion County		861		126	1,040	11.7	8.15		18.5	3
Quebec, 140					70.3	11.8	8.30			
Quebec, 140 & R					68.2	12.5	7.50			
Refractory										
ESP										
Philadelphia (NW1)		988			2,190	13.9	5.55	24.9	227	4
Philadelphia (NW2)		943			2,380	14.8	4.7	22.6	182	4
CYC										
Mayport	50			223	237	12.8	7.70		31.0	
SD/FF										
Tsushima				210	504	14.2	6.20	26.8		
EGB										
Pittsfield						10.7				

TABLE 7-3a. STARVED-AIR FACILITY STRUCTURAL DESIGN DATA

	Chamber configuration						
	Primary chamber		Secondary chamber			Grate data	
Facility	Geometric configuration	Volume, m^3	Geometric configuration	Volume, m^3	Heat transfer area, m^2	Manufacturer	Capacity, Mg/d
Barron County							45
Cattaraugus Co.							36
Dyersburg							91
N. Little Rock							23
Prince Edward Island							33
Red Wing							33
Tuscaloosa							82

TABLE 7-3b. STARVED-AIR FACILITY AIRFLOW DESIGN DATA

	Primary air							Secondary air				
				Flow distribution, percent						Nozzle data		
Facility	No. of plenums	No. of controlled flows	Flow rate, m^3/min	Feed	Dry	Combustion	Burnout	Location	Flow direction	Number	Type	Velocity, m/s

TABLE 7-4. STARVED AIR OPERATING DATA FOR MUNICIPAL WASTE COMBUSTOR FACILITIES

		Temperatures					Stack gas concentrations				
Facility name	Feed rate, % design	Primary chamber, °C	Secondary chamber, °C	Boiler outlet, °C	Stack, °C	Flow rate, Nm^3/min	O_2, %	CO_2, %	H_2O, %	CO, ppm	THC, ppm
Starved air											
No control device											
Cattaraugus County	94										
Dyersburg					254	231	12.8	7.03			
N. Little Rock		793	938	303	200						
Prince Edward Island, normal		693	904		184	169	12.2	8.00		43.0	0.5
Prince Edward Island, long		688	888		183	162	12.5	8.00		25.0	0.5
Prince Edward Island, high		704	1,080		183	131	9.10	11.1		27.0	0.7
Prince Edward Island, low		677	782		195	194	13.5	7.00		28.0	0.7
ESP											
Tuscaloosa	90					1,270	11.3	7.00			

TABLE 7-5a. REFUSE DERIVED FUEL-FIRED FACILITY STRUCTURAL DESIGN DATA

	Chamber configuration						Grate data					
	Primary chamber		Secondary chamber		Heat transfer area							
Facility	Geometric configuration	Volume, m^3	Geometric configuration	Volume, m^3	Convective, m^2	Total, m^2	Manufacturer	No. of sections	Pressure drop, kPa	Capacity, Mg/d	Fuel grade	Fuel charging mechanism
Akron										910		
Albany										272		
Hamilton-Wentworth										272		
Malmo										218		
Wright Pat. AFB[a]												
Niagara										1,100		

[a] Originally designed to burn coal, retrofitted to burn RDF.

TABLE 7-5b. REFUSE DERIVED FUEL-FIRED FACILITY AIRFLOW DESIGN DATA

	Primary air							Secondary air				
				Flow distribution, percent						Nozzle data		
Facility	No. of plenums	No. of controlled flows	Flow rate, m^3/min	Feed	Dry	Combustion	Burnout	Location	Flow direction	Number	Type	Velocity, m/s

TABLE 7-6. RDF-FIRED OPERATING DATA FOR MUNICIPAL WASTE COMBUSTOR FACILITIES

Facility name	Feed rate, % design	Temperatures			Flow rate, Nm^3/min	Stack gas concentrations				
		Furnace, °C	Boiler outlet, °C	Stack, °C		O_2, %	CO_2, %	H_2O, %	CO, ppm	THC, ppm
RDF fired										
ESP										
Akron				232	1,390	12.7	8.10			
Albany				201	2,190	11.3	9.50	13.4	274	
Niagara	75-90				4,040					
CYC/ESP										
Wright Pat. AFB					1,380		7.60			
Wright Pat. AFB			150	151						
CYC/DI/ESP/FF										
Malmo		816	283		943	7.60	11.5			

Control device design and operating characteristics in SI units

7-7 Electrostatic Precipitator Design Specifications

7-8 Electrostatic Precipitator Operating Conditions

7-9 Dry Scrubber/Fabric Filter System Design Specifications

7-10 Dry Scrubber/Fabric Filter System Operating Conditions

7-11 Fabric Filter or Scrubber Design Specifications

7-12 Fabric Filter or Scrubber Operating Conditions

TABLE 7-7. ELECTROSTATIC PRECIPITATOR DESIGN SPECIFICATIONS

	Particulate matter									
Facility name	Collection efficiency, %	Emissions, mg/Nm^3	Specific collection area, m^2/m^3/min	No. of fields	Collection plate area, m^2	Electrical power, kVA	Aspect ratio, length/height	Inlet gas flow rate, m^3/min	Inlet gas temp., °C	Gas velocity, m/s
Mass burn										
Waterwall										
ESP										
Baltimore				4	9,320			4,925	213	
Braintree	93.0		0.431	1	440			1,020		1.04
Chicago	97.0	114						3,820	260	0.91
Hampton (1981)				2						
Hampton (1983)				2						
Hampton (1984)				2						
North Andover		115		3						
Peekskill (4/85)		68		3						
Saugus				2						
SD/ESP										
Munich				2					149	
CYC/DI/ESP/FF										
Malmo								1,300	220	
Refractory										
ESP										
Philadelphia (NW1)	98.1		0.675	2	4,400			6,510	288	1.15
Philadelphia (NW2)	98.1		0.675	2	4,400			6,510	288	1.15
CYC/ESP										
Washington, D.C.	95.0			2						
Starved air										
ESP										
Tuscaloosa	50.0	68.6	0.458	2	985	27.0	0.52	2,150	177	1.27
RDF fired										
ESP										
Albany				3						
CYC/DI/ESP/FF										
Malmo								1,300	220	

TABLE 7-8. ELECTROSTATIC PRECIPITATOR OPERATING CONDITIONS

Facility name	Test condition	Particulate matter			Gas temp., °C	Gas flow rate, m^3/min	Secondary voltage, kVDC			Secondary current, mADC		
		Collection efficiency, %	Emissions at 12% CO_2 mg/Nm^3	Stack opacity, %			First field	Second field	Third field	First field	Second field	Third field
Mass burn												
Waterwall												
ESP												
Baltimore	Normal	99.9	6.86									
Braintree	Normal	75.7	547		198[a]	1,020[a]						
Chicago	Normal				236[b]	2,830[b]						
Hampton (1981)	Normal				275[a]	1,160[a]						
Hampton (1983)	Normal				271[b]	798[b]	22.0	22.0		68.0	216	
Hampton (1984)	Normal		342		258[a]	594[a]						
Peekskill (4/85)	Normal		37.3									
ESP/WS												
Kure	Normal	98.4	68.6		277[b]	1,130[b]						
CYC/DI/ESP/FF												
Malmo	Normal	99.5	22.9									
Refractory												
ESP												
Philadelphia (MW1)	Normal		252		267[a]	5,380[a]				430	300	
Philadelphia (MW2)	Normal		1,100		267[a]	5,660[a]				275	575	
Starved air												
ESP												
Tuscaloosa	Normal			3	323[b]	2,400[b]	24.0	20.0		43.0	92.0	
RDF fired												
ESP												
Albany	Normal	97.0	318		201[a]	4,080[a]	31.0	28.0	28.0	150	280	280
CYC/ESP												
Wright Pat. AFB	Normal				236[a]	2,580[a]						
Wright Pat. AFB	Dense RDF		11.4		139[a]							
CYC/DI/ESP/FF												
Malmo	RDF	99.5										

[a] Control device outlet.

[b] Control device inlet.

TABLE 7-9. DRY SCRUBBER/FABRIC FILTER SYSTEM DESIGN SPECIFICATIONS

Facility name	Particulate matter: Collection efficiency, %	Particulate matter: Emissions, mg/Nm^3	Inlet gas flow rate, m^3/min	Reagent	Reagent feed method	Gas temperature: Inlet, °C	Gas temperature: Outlet, °C	Bag material	A/C ratio, m/min[a]	Bag cleaning method
Mass burn										
Waterwall										
CYC/DI/ESP/FF										
Malmo		50.1	1,300	$Ca(OH)_2$	Nozzles	220				
WSH/DI/FF										
Quebec[b]				$Ca(OH)_2$	Dry or wet					
Wurzburg					Dry			Teflon	1.3	Pulse-jet
SD/FF										Pulse-jet
Marion County			1,740[c]			227-268	126		0.713	Reverse air
Refractory										
SD/FF										
Tsushima				$Ca(OH)_2$	Two fluid nozzles	360		Fiberglass		Reverse air
RDF fired										
CYC/DI/ESP/FF										
Malmo		50.1	1,300	$Ca(OH)_2$	Nozzles	220				

[a] A/C ratio = air-to-cloth ratio = gas flow rate÷bag area.

[b] These data also apply to the SD/FF pilot-scale tests.

[c] At 227°C.

TABLE 7-10. DRY SCRUBBER/FABRIC FILTER SYSTEM OPERATING CONDITIONS

Facility name	Test condition	Particulate matter		Gas flow rate, m^3/min	Gas temperature		Stoichio-metric ratio	Reagent feed rate, kg/h	Pressure drop	
		Collection efficiency, %	Emissions at 12% CO_2, mg/Nm^3		Inlet, °C	Outlet, °C			Scrubber, kPa	Bags, kPa
Mass burn										
Waterwall										
CYC/DI/ESP/FF										
Malmo	Normal	99.5	22.9							
WSH/DI/FF										
Quebec[a]	Pilot DS	99.9		125[b]	263	155		3.58		
Wurzburg	Normal			1,410[c]	220	185				
Refractory										
SD/FF										
Tsushima	Normal	99.4	27.5	1,110[b]	354	204		19.9	0.675	1.60
RDF fired										
CYC/DI/ESP/FF										
Malmo	RDF		99.5							

[a] These data also apply to the SD/FF pilot-scale tests.
[b] Control device inlet.
[c] Control device outlet.

TABLE 7-11. FABRIC FILTER OR SCRUBBER DESIGN SPECIFICATIONS

Facility name	Particulate matter		Inlet gas flow rate, m^3/min	Inlet gas temp., °C	Fabric filter			Scrubber		
	Collection efficiency, %	Emissions, mg/Nm^3			A/C ratio, m/min	Bag cleaning method	Bag material	Type	Pressure drop, kPa	Liquid rate, lpm
Mass burn										
Waterwall										
ESP/WS										
Kure								TCA		
SD/ESP										
Munich				2[illegible]						
Refractory										
WS										
Alexandria								Imp.		
Nicosia								Imp.		3,980

TABLE 7-12. FABRIC FILTER OR SCRUBBER OPERATING CONDITIONS

Facility name	Test condition	Particulate matter: Collection efficiency, %	Particulate matter: Emissions at 12% CO_2, mg/Nm^3	Inlet gas flow rate, m^3/min	Gas temperature: Inlet, °C	Gas temperature: Outlet, °C	Pressure drop, kPa	Bag cleaning cycle, min	Stoichiometric ratio
Mass burn									
Waterwall									
CYC/FF									
Gallatin	Normal	98.9	73.4	518	230	172			
ESP/WS									
Kure	Normal	98.4	68.6						
SD/ESP									
Munich	MSW only			4,310	266	159			6.5[a]
CYC/DI/ESP/FF									
Malmo	Normal	99.5	22.9						
WSH/DI/FF									
Quebec									
Refractory									
SD/FF									
Tsushima	Normal	99.4	27.5						
RDF fired									
CYC/DI/ESP/FF									
Malmo	RDF	99.5							

[a] Reagent versus HCl and SO_2.

Criteria pollutants in SI units

7-13 Summary of Particulate Emissions From MWC Facilities

7-14 Summary of Carbon Monoxide Emissions From MWC Facilities

7-15 Summary of Sulfur Dioxide Emissions From MWC Facilities

7-16 Summary of Oxides of Nitrogen Emissions From MWC Facilities

TABLE 7-13. SUMMARY OF PARTICULATE EMISSIONS FROM MWC FACILITIES

Facility name	Test condition	Emissions upstream from control device		Emissions downstream from control device		Control effi-ciency, %
		mg/Nm^3 at 12% CO$_2$	kg/Mg feed	mg/Nm^3 at 12% CO$_2$	kg/Mg feed	
Mass burn						
Waterwall						
ESP						
Baltimore, 1/85	Normal			5.49	0.025	
Baltimore, 5/85	Normal	4,690	23.2	6.18	0.029	99.9
Braintree	Normal	2,240	6.50	546	1.51	75.6
Hampton (1981)	Normal			917	3.47	
Hampton (1982)	Normal			424	1.96	
Hampton (1984)	Normal			162		
McKay Bay (Unit 1)[a b]	Normal	4,490		29.7		
McKay Bay (Unit 2)[b]	Normal	4,980		26.3		
McKay Bay (Unit 3)[b]	Normal	3,690		6.41		
McKay Bay (Unit 4)[b]	Normal	3,850		17.6		
N. Andover	Normal	2,140		11.2		99.5
Peekskill (4/85)	Normal			98.6		
Tulsa (Unit 1)	Normal			21.7	0.089	
Tulsa (Unit 2)	Normal			11.2	0.047	
CYC/FF						
Gallatin	Normal	6,690	21.3	73.4	0.343	98.9
ESP/WS						
Kure	Normal	4,300	18.2	68.6	0.204	98.4
SD/ESP						
Munich	MSW only	6,610	24.9	23.8	0.092	99.6
CYC/DI/ESP/FF						
Malmo	Normal	4,450	25.4	23.2	0.132	99.5
WSH/DI/FF						
Quebec	110	8,460				
Quebec	125	7,910				
Quebec	140	6,650				
Quebec	200	5,980				
Wurzburg	Normal			9.15	0.027	
SD/FF						
Marion County	Normal			16.0	0.077	
Quebec	140	5,790				
Quebec	140 & R.	7,650				
Refractory						
ESP						
Philadelphia (NW1)	Normal			252		
Philadelphia (NW2)	Normal			1,330		
CYC						
Mayport	MSW/waste oil			1,530	6.49	
SD/FF						
Tsushima	Normal	4,460	12.4	27.5	0.076	99.4
Starved air						
No control device						
Dyersburg	Normal	303	1.30			
N. Little Rock, 3/78[c]	Normal	327				
N. Little Rock, 5/78[c]	Normal	436				
N. Little Rock, 10/78[c]	Normal	297	1.52			
Prince Edward Island	Normal	214	0.840			
Prince Edward Island	Long	234	0.870			
Prince Edward Island	High	255	1.0			
Prince Edward Island	Low	173	0.680			
ESP						
Barron County	Normal			22.9	0.098	
Red Wing	Normal			111	0.469	
Tuscaloosa[d]	Normal	197	0.727	142	0.523	27.9
RDF fired						
ESP						
Akron	Normal			533	1.32	
Albany	Normal	10,600	51.7	318	1.55	97.0
Hamilton-Wentworth[a]	F/None			715		
Hamilton-Wentworth[e]	F/Low back			88.5		
Hamilton-Wentworth	F/Back			518		
Hamilton-Wentworth[a]	F/Back, low front			212		
Hamilton-Wentworth[a]	H/None			230		
Hamilton-Wentworth[a]	H/Low back			122		
Niagara	Normal			220		

(continued)

TABLE 7-13. (continued)

Facility name	Test condition	Emissions upstream from control device		Emissions downstream from control device		Control efficiency, %
		mg/Nm³ at 12% CO_2	kg/Mg feed	mg/Nm³ at 12% CO_2	kg/Mg feed	
CYC/DI/ESP/FF Malmo	RDF	4,330	29.1			

[a] Average of two test runs.
[b] Control efficiency not calculated because inlet and outlet test runs were not simultaneous.
[c] Not corrected to dry standard conditions.
[d] Control efficiency is not typical of most properly maintained ESP's.
[e] One test run only.

TABLE 7-14. SUMMARY OF CARBON MONOXIDE EMISSIONS FROM MWC FACILITIES

Facility name	Test condition	Emissions upstream from control device		Emissions downstream from control device		Control efficiency, %
		ppmdv at 12% CO_2	kg/Mg feed	ppmdv at 12% CO_2	kg/Mg feed	
Mass burn						
Waterwall						
ESP						
Baltimore, 1/85	Normal			19.6	0.106	
Braintree	Normal			1,350	4.36	
Chicago	Normal	189	0.842	197	0.848	
Hampton (1983)	Normal			1,050		
Hampton (1984)	Normal			242		
McKay Bay (unit 1)[a]	Normal			30		
McKay Bay (unit 2)[a]	Normal			35		
McKay Bay (unit 3)[a]	Normal			31.7		
McKay Bay (unit 4)[a]	Normal			31.7		
N. Andover	Normal			42.4		
Saugus	Normal			36.3		
Tulsa (Unit 1)	Normal			20.1	0.049	
Tulsa (Unit 2)	Normal			23.8	0.059	
CYC/FF						
Gallatin	Normal			516	2.25	
ESP/WS						
Kure	Normal	630	2.54			
CYC/DI/ESP/FF						
Malmo	Normal			158	1.05	
WSH/DI/FF						
Quebec	110			151		
Quebec	125			189		
Quebec	140			211		
Quebec	200			166		
Wurzburg	Normal			41	0.127	
SD/FF						
Marion County	Normal			18.5	0.098	
Quebec	140			133		
Quebec	140 & R.			174		
Refractory						
ESP						
Philadelphia (NW1)	Normal			515		
Philadelphia (NW2)	Normal			464		
CYC						
Mayport	MSW/waste oil	48.3	0.276			
Starved air						
No control device						
N. Little Rock 10/78[b]	Normal	84.9	0.5			
Prince Edward Island	Normal	67.0	0.318			
Prince Edward Island	Long	40.0	0.177			
Prince Edward Island	High	33.0	0.146			
Prince Edward Island	Low	52.0	0.253			
ESP						
Barron County	Normal			3.24	0.015	
Red Wing	Normal			<2.11	<0.0106	
RDF fired						
ESP						
Albany	Normal			346	1.96	
Hamilton-Wentworth[c]	F/None			636		
Hamilton-Wentworth[d]	F/Low back			501		
Hamilton-Wentworth	F/Back			430		
Hamilton-Wentworth[c]	F/Back, low front			411		
Hamilton-Wentworth[c]	H/None			2,090		
Hamilton-Wentworth[c]	H/Low back			1,210		
CYC/DI/ESP/FF						
Malmo	RDF			217	1.70	

[a] Not corrected to 12 percent CO_2

[b] Not corrected to dry standard conditions.

[c] Average of two test runs.

[d] One test run only.

TABLE 7-15. SUMMARY OF SULFUR DIOXIDE EMISSIONS FROM MWC FACILITIES

Facility name	Test condition	Emissions upstream from control device		Emissions downstream from control device		Control effi- ciency, %
		ppmdv at 12% CO_2	kg/Mg feed	ppmdv at 12% CO_2	kg/Mg feed	
Mass burn						
Waterwall						
ESP						
Baltimore, 1/85	Normal			114	1.37	
Braintree	Normal			136	1.00	
McKay Bay (Unit 1)	Normal			98.6		
McKay Bay (Unit 3)	Normal			111		
McKay Bay (Unit 4)[a]	Normal			177		
Tulsa (Unit 1)	Normal			94.9	0.995	
Tulsa (Unit 2)	Normal			80.9	0.917	
CYC/FF						
Gallatin	Normal	141	1.19	141	1.75	
ESP/WS						
Kure	Normal	89.6	1.01	13.5	0.098	87.1
SD/ESP						
Munich[b]	MSW only	92.0	1.16	21.7	0.281	76.4
WSH/DI/FF						
Quebec	110	128		4.86		96.2
Quebec	125	127		10.8		91.5
Quebec	140	129		28.2		78.1
Quebec	200	118		90.3		23.5
Wurzburg	Normal			209	1.63	
SD/FF						
Marion County	Normal			41.5	0.517	
Quebec	140	108		35.8		67.0
Quebec	140 & R.	111		44.8		59.6
Refractory						
ESP						
Philadelphia (NW1)	Normal			401		
Philadelphia (NW2)	Normal			375		
SD/FF						
Tsushima	Normal	12.7	0.090	0.040	0.0004	99.7
Starved air						
No control device						
N. Little Rock, 10/78[c]	Normal	<29.3	<0.39			
Prince Edward Island	Normal	61.0	0.662			
Prince Edward Island	Long	83.0	0.840			
Prince Edward Island	High	75.0	0.759			
Prince Edward Island	Low	87.0	0.966			
ESP						
Red Wing	Normal			124	1.42	
RDF fired						
ESP						
Albany	Normal			188	2.50	
Hamilton-Wentworth[a]	F/None			58.9		
Hamilton-Wentworth	F/Back			54.7		
Hamilton-Wentworth[a]	F/Back, low front			57.3		
Hamilton-Wentworth[a]	H/None			49.3		
Hamilton-Wentworth[a]	H/Low back			67.3		
Niagara	Normal				1.41	

[a] Average of two test runs.

[b] This data represents a combined SO_2 and SO_3 value because separate values were not reported.

[c] Not corrected to dry standard conditions.

TABLE 7-16. SUMMARY OF OXIDES OF NITROGEN EMISSIONS FROM MWC FACILITIES

Facility name	Test condition	Emissions upstream from control device		Emissions downstream from control device		Control efficiency, %
		ppmdv at 12% CO_2	kg/Mg feed	ppmdv at 12% CO_2	kg/Mg feed	
Mass burn						
Waterwall						
ESP						
Baltimore, 1/85	Normal			196	1.69	
Braintree	Normal			153	0.812	
McKay Bay (Unit 1)	Normal			103		
McKay Bay (Unit 2)	Normal			39		
McKay Bay (Unit 3)	Normal			100		
McKay Bay (Unit 4)	Normal			106		
Tulsa (Unit 1)	Normal			358	2.86	
Tulsa (Unit 2)	Normal			376	3.08	
CYC/FF						
Gallatin	Normal	140	1.10			
ESP/WS						
Kure	Normal	159	1.25			
WSH/DI/FF						
Wurzburg	Normal			294	1.59	
SD/FF						
Marion County	Normal			294	2.63	
Refractory						
ESP						
Philadelphia (NW1)	Normal			195		
Philadelphia (NW2)	Normal			215		
SD/FF						
Tsushima	Normal			168	0.895	
Starved air						
No control device						
N. Little Rock, 10/78[a]	Normal	240	1.84			
Prince Edward Island	Normal	309	2.41			
Prince Edward Island	Long	271	1.97			
Prince Edward Island	High	258	1.88			
Prince Edward Island	Low	292	2.33			
ESP						
Red Wing	Normal			255	2.10	
Tuscaloosa	Normal			278	1.92	
RDF fired						
ESP						
Albany	Normal			263	2.45	
Niagara	Normal				1.96	

[a] Not corrected to dry standard conditions.

Metals in SI units

7-17 Summary of Arsenic Emissions From MWC Facilities

7-18 Summary of Beryllium Emissions From MWC Facilities

7-19 Summary of Cadmium Emissions From MWC Facilities

7-20 Summary of Total Chromium Emissions From MWC Facilities

7-21 Summary of Lead Emissions From MWC Facilities

7-22 Summary of Mercury Emissions From MWC Facilities

7-23 Summary of Nickel Emissions From MWC Facilities

TABLE 7-17. SUMMARY OF ARSENIC EMISSIONS FROM MWC FACILITIES

Facility name	Test condition	Emissions upstream from control device			Emissions downstream from control device			Control efficiency, %
		µg/Nm³ at 12% CO_2	µg/g Partic-ulate	mg/Mg feed	µg/Nm³ at 12% CO_2	µg/g Partic-ulate	mg/Mg feed	
Mass burn								
Waterwall								
ESP								
Baltimore, 5/85[a]	Normal	240	51.2	1,390	6.29	1,020	30.4	97.4
Braintree	Normal	143	63.8	415	45.8	83.9	126	68.0
Hampton (1982)	Normal				233	549	1,080	
N. Andover	Normal	934	436		10.4	929		98.9
CYC/FF								
Gallatin	Normal	487	72.9	1,590				
ESP/WS								
Kure	Normal	288	67.0	7,500				
SD/ESP								
Munich	MSW only				0.452	19.0	1.80	
WSH/DI/FF								
Quebec	110	161	19.0		0.022			>99.9
Quebec	125	112	14.2		0.044			>99.9
Quebec	140	140	21.1		0.043			>99.9
Quebec	200	80.2	13.4		0.073			99.9
Wurzburg[b]	Normal				0.007	0.754	0.020	
SD/FF								
Quebec	140	111	19.2		0.042			>99.9
Quebec	140 & R.	135	17.7		0.032			>99.9
Refractory								
CYC/ESP								
Washington, D.C.	Normal					310		
WS								
Alexandria	Normal					210		
Nicosia	Normal					200		
SD/FF								
Tsushima[b]	Normal	61.5	13.8	200	0.327	11.9	0.800	99.5
Starved air								
No control device								
Dyersburg	Normal	116	382	497				
Prince Edward Island	Normal	6.09	28.5	26.0				
Prince Edward Island	Long	10.2	43.6	36.0				
Prince Edward Island	High	17.4	68.2	71.0				
Prince Edward Island	Low	8.18	47.3	33.0				
ESP								
Barron County	Normal				19.5	850	83	
Red Wing	Normal				28.8	259	124	
Tuscaloosa[a]	Normal	119	605	442	43.7	308	164	63.3
RDF fired								
ESP								
Akron	Normal				160	300	376	
Albany	Normal				19.1	60.1	93.0	
Niagara	Normal						96.0	

[a] Specific arsenic run used to measure reported data.

[b] One test run only.

TABLE 7-18. SUMMARY OF BERYLLIUM EMISSIONS FROM MWC FACILITIES

Facility name	Test condition	Emissions upstream from control device			Emissions downstream from control device			Control efficiency, %
		µg/Nm^3 at 12% CO_2	µg/g Partic-ulate	mg/Mg feed	µg/Nm^3 at 12% CO_2	µg/g Partic-ulate	mg/Mg feed	
Mass burn								
Waterwall								
ESP								
Braintree[a]	Normal	0.082	0.041	0.238	0.085	0.156	0.241	
Hampton (1982)	Normal				0.020	0.047	0.092	
McKay Bay (Unit 1)	Normal				0.166			
McKay Bay (Unit 2)	Normal				0.103			
McKay Bay (Unit 3)	Normal				0.254			
McKay Bay (Unit 4)	Normal				0.0915			
Tulsa (Units 1 and 2)	Normal				0.003	0.140	0.012	
CYC/FF								
Gallatin	Normal	7.35	1.10	24.0				
SD/ESP								
Munich	MSW only				0.0005	0.021	0.187	
WSH/DI/FF								
Quebec[b]	110	0.0			0.0			
Quebec[b]	125	0.0			0.0			
Quebec[b]	140	0.0			0.0			
Quebec[b]	200	0.0			0.0			
SD/FF								
Marion County	Normal				0.0025		0.0107	
Quebec[b]	140	0.0			0.0			
Quebec[b]	140 & R.	0.0			0.0			
Refractory								
SD/FF								
Tsushima[c]	Normal	46.9	10.5	150	0.327	11.9	0.800	99.3
Starved air								
No control device								
Dyersburg	Normal	0.110	0.363	0.427				
N. Little Rock, 10/78[d]	Normal	0.334	1.12	1.8				
ESP								
Red Wing	Normal				0.0961	0.866	0.413	
RDF fired								
ESP								
Albany	Normal				20.6	64.8	100	
Niagara	Normal						0.481	

[a] An increase in concentration occurred across the control device; however, the difference between inlet and outlet values is within the imprecision associated with the sampling and analysis techniques.

[b] A 0.0 indicates below detection limit (values of detection limit not yet received).

[c] One test run only.

[d] Not corrected to dry standard conditions.

TABLE 7-19. SUMMARY OF CADMIUM EMISSIONS FROM MWC FACILITIES

Facility name	Test condition	Emissions upstream from control device			Emissions downstream from control device			Control efficiency, %
		$\mu g/Nm^3$ at 12% CO_2	µg/g Partic-ulate	mg/Mg feed	$\mu g/Nm^3$ at 12% CO_2	µg/g Partic-ulate	mg/Mg feed	
Mass burn								
Waterwall								
ESP								
Braintree	Normal	1,260	563	3,660	475	870	1,310	62.3
Chicago	Normal				293		1,210	
Hampton (1982)	Normal				500	1,180	2,320	
N. Andover	Normal	446	208		22.3	1,990		95
CYC/FF								
Gallatin	Normal	3,620	541	11,800				
ESP/WS								
Kure	Normal	984	229	25,500				
SD/ESP								
Munich	MSW only				8.57	360	35.0	
CYC/DI/ESP/FF								
Malmo	Normal	689	155	3,930	6.22	268	35.5	99.1
WSH/DI/FF								
Quebec	110	1,390	165		0.483			>99.9
Quebec	125	1,450	184		0.480			>99.9
Quebec[a]	140	1,610	242		0.0			
Quebec	200	1,050	176		0.636			>99.9
Wurzburg[b]	Normal				6.86	750	20.4	
SD/FF								
Quebec[a]	140	1,270	216		0.0			
Quebec[a]	140 & R.	1,220	160		0.0			
Refractory								
CYC/ESP								
Washington, D.C.	Normal					1,900		
WS								
Alexandria	Normal					1,100		
Nicosia	Normal					1,500		
SD/FF								
Tsushima[b]	Normal	120	26.9	350	11.3	412	55.0	90.6
Starved air								
No control device								
Dyersburg	Normal	238	784	1,020				
N. Little Rock, 10/78[c]	Normal	360	1,210	1,930				
Prince Edward Island	Normal	942	4,400	3,790				
Prince Edward Island	Long	800	3,420	3,030				
Prince Edward Island	High	814	3,190	3,160				
Prince Edward Island	Low	639	3,690	2,570				
ESP								
Barron County	Normal				20.9	913	82.9	
Red Wing	Normal				203	1,830	872	

(continued)

TABLE 7-19. (continued)

Facility name	Test condition	Emissions upstream from control device			Emissions downstream from control device			Control efficiency, %
		μg/Nm^3 at 12% CO$_2$	μg/g Particulate	mg/Mg feed	μg/Nm^3 at 12% CO$_2$	μg/g Particulate	mg/Mg feed	
RDF fired								
ESP								
Akron	Normal				373	700	923	
Albany					33.7	106	164	
Niagara	Normal						265	
CYC/DI/ESP/FF								
Malmo	RDF	488	113	3,280				

[a] A 0.0 indicates below detection limit (values of detection limit not yet received).
[b] One test run only.
[c] Not corrected to dry standard conditions.

TABLE 7-20. SUMMARY OF TOTAL CHROMIUM EMISSIONS FROM MWC FACILITIES

Facility name	Test condition	Emissions upstream from control device: µg/Nm^3 at 12% CO$_2$	Emissions upstream from control device: µg/g Particulate	Emissions upstream from control device: mg/Mg feed	Emissions downstream from control device: µg/Nm^3 at 12% CO$_2$	Emissions downstream from control device: µg/g Particulate	Emissions downstream from control device: mg/Mg feed	Control efficiency, %
Mass burn								
Waterwall								
ESP								
Baltimore, 5/85[a]	Normal	2,180	465	10,800	21.3	3,450	101	99.0
Braintree	Normal	627	280	1,820	106	194	293	83.1
Hampton (1982)	Normal				283	668	1,310	
N. Andover	Normal	4,280	2,000		767	68,500		82.1
CYC/FF								
Gallatin	Normal	1,200	180	3,930				
ESP/WS								
Kure	Normal	579	135	15,000				
SD/ESP								
Munich	MSW only				1,020	43,000	4,020	
WSH/DI/FF								
Quebec	110	3,380	399		0.483			>99.9
Quebec	125	2,080	263		0.480			>99.9
Quebec	140	2,150	323		1.07			>99.9
Quebec	200	1,950	326		0.542			>99.9
Wurzburg[b]	Normal				0.618	67.5	1.84	
SD/FF								
Quebec	140	1,510	260		0.229			>99.9
Quebec	140 & R.	1,770	231		0.774			>99.9
Refractory								
CYC/ESP								
Washington, D.C.	Normal					870		
WS								
Alexandria	Normal					490		
Nicosia	Normal					105		
SD/FF								
Tsushima[b]	Normal	2,700	605	8,000	5.35	195	13.0	99.8
Starved air								
No control device								
Dyersburg	Normal	394	1,300	1,690				
N. Little Rock, 10/78[c]	Normal	3.23	10.9	17.3				
Prince Edward Island	Normal	43.6	204	173				
Prince Edward Island	Long	26.5	113	99				
Prince Edward Island	High	117	459	445				
Prince Edward Island	Low	25.4	147	102				
ESP								
Barron County	Normal				3.57	156	13.8	
Red Wing	Normal				24.5	221	105	
Tuscaloosa[d]	Normal	36.6	186	135	25.7	181	96.4	25.8

(continued)

TABLE 7-20. (continued)

Facility name	Test condition	Emissions upstream from control device			Emissions downstream from control device			Control efficiency, %
		µg/Nm^3 at 12% CO$_2$	µg/g Particulate	mg/Mg feed	µg/Nm^3 at 12% CO$_2$	µg/g Particulate	mg/Mg feed	
RDF fired								
ESP								
Akron	Normal				493	925	1,220	
Albany	Normal				6,660	20,900	32,400	
Niagara	Normal						452	

[a] Inlet hexavalent chromium value of 0.5 µg/g presented in test report.
[b] One test run only.
[c] Not corrected to dry standard conditions.
[d] Control efficiency is not typical of most properly maintained ESP's.

TABLE 7-21. SUMMARY OF LEAD EMISSIONS FROM MWC FACILITIES

		Emissions upstream from control device			Emissions downstream from control device			
Facility name	Test condition	µg/Nm^3 at 12% CO$_2$	µg/g Particulate	mg/Mg feed	µg/Nm^3 at 12% CO$_2$	µg/g Particulate	mg/Mg feed	Control efficiency, %
Mass burn								
Waterwall								
ESP								
Braintree	Normal	34,000	15,200	98,700	15,400	28,200	42,500	54.7
Hampton (1982)	Normal				9,490	22,400	44,000	
McKay Bay (Unit 1)	Normal				3,090			
McKay Bay (Unit 2)	Normal				1,080			
McKay Bay (Unit 3)	Normal				886			
McKay Bay (Unit 4)	Normal				1,180			
Tulsa (Units 1 and 2)	Normal				415	19,100	1,690	
CYC/FF								
Gallatin	Normal	41,900	6,260	137,000				
ESP/WS								
Kure	Normal	4,830	1,120	125,000				
SD/ESP								
Munich	MSW only				88.1	3,700	350	
CYC/DI/ESP/FF								
Malmo	Normal	14,300	3,210	81,600	131	5,650	747	99.1
WSH/DI/FF								
Quebec	110	45,000	5,320		4.30			>99.9
Quebec	125	48,400	6,110		2.89			>99.9
Quebec	140	36,100	5,430		4.92			>99.9
Quebec	200	36,100	6,030		6.53			>99.9
Wurzburg[a]	Normal				13.7	1,500	40.9	
SD/FF								
Marion County	Normal				25.1		146	
Quebec	140	37,500	6,490		1.23			>99.9
Quebec	140 & R.	36,000	4,710		6.44			>99.9
Refractory								
CYC/ESP								
Washington, D.C.	Normal					78,000		
WS								
Alexandria	Normal					97,000		
Nicosia	Normal					69,000		
SD/FF								
Tsushima[a]	Normal	2,810	631	8,500	20.8	758	50.0	99.3
Starved air								
No control device								
Dyersburg	Normal	15,200	50,000	65,000				
N. Little Rock, 10/78[b]	Normal	12,500	42,100	67,200				
Prince Edward Island	Normal	14,400	67,300	54,800				
Prince Edward Island	Long	15,500	66,200	57,800				
Prince Edward Island	High	15,500	60,800	60,000				
Prince Edward Island	Low	8,560	49,500	34,200				
ESP								
Barron County	Normal				237	10,300	965	
Red Wing	Normal				3,390	34,300	14,600	

(continued)

TABLE 7-21. (continued)

Facility name	Test condition	Emissions upstream from control device			Emissions downstream from control device			Control efficiency, %
		$\mu g/Nm^3$ at 12% CO_2	µg/g Particulate	mg/Mg feed	$\mu g/Nm^3$ at 12% CO_2	µg/g Particulate	mg/Mg feed	
RDF fired								
ESP								
Akron	Normal				9,600	18,000	23,700	
Albany	Normal				973	3,060	4,730	
Niagara	Normal						6,450	
CYC/DI/ESP/FF								
Malmo	RDF	9,600	2,220	64,500				

[a] One test run only.

[b] Not corrected to dry standard conditions.

TABLE 7-22. SUMMARY OF MERCURY EMISSIONS FROM MWC FACILITIES

Facility name	Test condition	Emissions upstream from control device			Emissions downstream from control device			Control efficiency, %
		μg/Nm^3 at 12% CO_2	μg/g Particulate	mg/Mg feed	μg/Nm^3 at 12% CO_2	μg/g Particulate	mg/Mg feed	
Mass burn								
Waterwall								
ESP								
Braintree[a]	Normal	28.6	12.8	83.0	40.0	73.3	110	
Hampton (1982)	Normal				2,210	5,220	10,300	
McKay Bay (Unit 1)	Normal				647			
McKay Bay (Unit 2)	Normal				863			
McKay Bay (Unit 3)	Normal				931			
McKay Bay (Unit 4)	Normal				1,080			
Tulsa (Units 1 and 2)	Normal				419	19,300	1,790	
CYC/FF								
Gallatin	Normal	233	34.9	855				
ESP/WS								
Kure	Normal	8.69	2.02	225				
CYC/DI/ESP/FF								
Malmo	Normal	312	70.1	1,780	187	8,060	1,070	40.1
WSH/DI/FF								
Quebec	110	486	57.1		43.4			91.0
Quebec	125	521	65.7		13.7			97.4
Quebec	140	340	51.0		21.1			93.8
Quebec[a]	200	468	78.4		637			
SD/FF								
Marion County	Normal				280		1,440	
Quebec	140	192	33.3		10.4			94.6
Quebec	140 & R.	381	49.8		20.4			94.6
Refractory								
SD/FF								
Tsushima[b]	Normal	265	59.5	6,000	186	6,770	450	30.0
Starved air								
No control device								
Dyersburg	Normal	130	430	559				
Prince Edward Island	Normal	705	3,290	2,650				
Prince Edward Island	Long	538	2,300	1,970				
Prince Edward Island	High	471	1,850	3,600				
Prince Edward Island	Low	539	3,120	2,160				
ESP								
Red Wing[c]	Normal				596	5,370	2,560	
RDF fired								
ESP								
Akron	Normal				184	345	455	
Albany	Normal				441	1,390	2,140	
Niagara	Normal						1,580	
CYC/DI/ESP/FF								
Malmo	RDF	170	39.3	1,140				

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[a] An apparent increase in concentration occurred across the control device; however, no reason for this increase was indicated in the test reports.

[b] One test run only.

[c] Measured using $KMnO_4$ impinger method.

TABLE 7-23. SUMMARY OF NICKEL EMISSIONS FROM MWC FACILITIES

Facility name	Test condition	Emissions upstream from control device			Emissions downstream from control device			Control efficiency, %
		µg/Nm^3 at 12% CO$_2$	µg/g Particulate	mg/Mg feed	µg/Nm^3 at 12% CO$_2$	µg/g Particulate	mg/Mg feed	
Mass burn								
Waterwall								
ESP								
Hampton (1982)	Normal				227	535	1,050	
N. Andover	Normal	523	244		477	42,600		9
CYC/FF								
Gallatin	Normal	508	75.9	166				
ESP/WS								
Kure	Normal	387	89.9	10,000				
SD/ESP								
Munich	MSW only				476	20,000	1,870	
WSH/DI/FF								
Quebec	110	1,070	127		1.43			99.9
Quebec	125	1,930	244		0.480			>99.9
Quebec	140	1,330	201		0.756			99.9
Quebec	200	867	145		1.60			99.8
Wurzburg[a]	Normal				0.277	30.2	0.825	
SD/FF								
Quebec	140	739	128		1.37			99.8
Quebec	140 & R.	2,690	351		2.23			99.9
Refractory								
CYC/ESP								
Washington, D.C.	Normal					170		
WS								
Alexandria	Normal					200		
Nicosia	Normal					79.0		
SD/FF								
Tsushima[a]	Normal	2,290	512	7,000	297	10,800	750	87.0
Starved air								
No control device								
Dyersburg	Normal	109	361	470				
N. Little Rock, 10/78[b]	Normal	5.77	19.4	31				
Prince Edward Island	Normal	242	1,130	961				
Prince Edward Island	Long	262	1,120	1,000				
Prince Edward Island	High	553	2,170	2,170				
Prince Edward Island	Low	481	2,780	1,940				
ESP								
Barron County	Normal				<2.76	<121	<13.8	
Red Wing	Normal				<1.92	<17.3	<8.25	
RDF fired								
ESP								
Akron	Normal				128	240	316	
Albany	Normal				3,590	11,300	17,500	
Niagara	Normal						374	

[a] One test run only.
[b] Not corrected to dry standard conditions.

Acid gases in SI units

7-24 Summary of Hydrogen Chloride Emissions From MWC Facilities
7-25 Summary of Hydrogen Fluoride Emissions From MWC Facilities
7-26 Summary of Sulfur Trioxide Emissions From MWC Facilities

TABLE 7-24. SUMMARY OF HYDROGEN CHLORIDE EMISSIONS FROM MWC FACILITIES

		Emissions upstream from control device		Emissions downstream from control device		
Facility name	Test condition	ppmdv at 12% CO_2	kg/Mg feed	ppmdv at 12% CO_2	kg/Mg feed	Control effi-ciency, %
Mass burn						
Waterwall						
ESP						
Hampton (1981)	Normal			179	1.10	
Hampton (1982)	Normal			268	1.89	
Tulsa (Unit 1)	Normal			421	2.51	
Tulsa (Unit 2)	Normal			402	2.60	
CYC/FF						
Gallatin	Normal	477	2.64			
ESP/WS						
Kure	Normal	1,010	6.28	211	0.947	79.1
SD/ESP						
Munich	MSW only	546	3.12	27.0	0.159	95.1
CYC/DI/ESP/FF						
Malmo	Normal	742	6.45	211		71.6
WSH/DI/FF						
Quebec	110	482		3.99		99.2
Quebec	125	498		10.1		98.0
Quebec	140	422		28.6		92.5
Quebec	200	429		104		76.9
Wurzburg	Normal			52.0	0.232	
SD/FF						
Marion County	Normal			12.0	0.0794	
Quebec	140	414		36.5		91.2
Quebec	140 & R.	476		41.8		91.2
Refractory						
ESP						
Philadelphia (NW1)	Normal			140		
Philadelphia (NW2)	Normal			64.8		
CYC						
Mayport	MSW/waste oil			308	2.79	
SD/FF						
Tsushima	Normal	313	1.32	7.50	0.031	97.6
Starved air						
None						
Dyersburg	Normal	159	1.04			
Prince Edward Island	Normal	716	4.42			
Prince Edward Island	Long	706	4.07			
Prince Edward Island	High	768	4.43			
Prince Edward Island	Low	627	3.97			
ESP						
Barron County	Normal			457	2.84	
Red Wing	Normal			1,270	8.27	
RDF fired						
ESP						
Akron	Normal			447	1.68	
Albany	Normal			348	2.57	
Niagara	Normal				2.54	
CYC/ESP						
Wright Pat. AFB	Dense RDF	95.9				
CYC/DI/ESP/FF						
Malmo	RDF	776	7.90			

TABLE 7-25. SUMMARY OF HYDROGEN FLUORIDE EMISSIONS FROM MWC FACILITIES

Facility name	Test condition	Emissions upstream from control device		Emissions downstream from control device		Control effi- ciency, %
		ppmdv at 12% CO_2	kg/Mg feed	ppmdv at 12% CO_2	kg/Mg feed	
Mass burn						
Waterwall						
ESP						
Hampton (1982)	Normal			1.30	0.005	
Tulsa (Unit 1)	Normal			7.21	0.024	
Tulsa (Unit 2)	Normal			6.27	0.022	
CYC/FF						
Gallatin	Normal	5.18	0.016			
ESP/WS						
Kure	Normal	2.96	0.009	0.935	0.003	68.4
Refractory						
SD/FF						
Tsushima	Normal	1.20	0.003	0.620	0.003	48.3
Starved air						
None						
Dyersburg	Normal	1.10	0.004			
Prince Edward Island	Normal	12.0	0.041			
Prince Edward Island	Long	10.8	0.034			
Prince Edward Island	High	15.6	0.049			
Prince Edward Island	Low	12.0	0.042			
RDF fired						
ESP						
Akron	Normal			2.12	0.004	

TABLE 7-26. SUMMARY OF SULFUR TRIOXIDE EMISSIONS FROM MWC FACILITIES

Facility name	Test condition	Emissions upstream from control device		Emissions downstream from control device		Control effi-ciency, %
		ppmdv at 12% CO_2	kg/Mg feed	ppmdv at 12% CO_2	kg/Mg feed	
Mass burn						
Waterwall						
ESP						
Tulsa (Unit 1)	Normal			10.1	0.084	
Tulsa (Unit 2)	Normal			9.76	0.086	
CYC/FF						
Gallatin	Normal	85.3	1.04	44.5	0.830	47.8
ESP/WS						
Kure	Normal	5.58	0.074	3.96	0.058	29.0
SD/ESP						
Munich[a]	MSW only	92.0	1.16	21.7	0.281	76.4

[a] This data represents a combined SO_2 and SO_3 value because separate values were not reported.

PCDD in SI units

7-27 Summary of 2,3,7,8-Tetrachlorodibenzo-p-dioxin Emissions From MWC Facilities

7-28 Summary of Total Tetrachlorodibenzo-p-dioxin Emissions From MWC Facilities

7-29 Summary of Total Pentachlorodibenzo-p-dioxin Emissions From MWC Facilities

7-30 Summary of Total Hexachlorodibenzo-p-dioxin Emissions From MWC Facilities

7-31 Summary of Total Heptachlorodibenzo-p-dioxin Emissions From MWC Facilities

7-32 Summary of Total Octachlorodibenzo-p-dioxin Emissions From MWC Facilities

7-33 Summary of Tetra- Through Octachlorodibenzo-p-dioxin Emissions From MWC Facilities

7-34 Summary of Total Measured Chlorodibenzo-p-dioxin Emissions From MWC Facilities

TABLE 7-27. SUMMARY OF 2,3,7,8-TETRACHLORODIBENZO-p-DIOXIN EMISSIONS FROM MWC FACILITIES

		Emissions upstream from control device			Emissions downstream from control device			
Facility name	Test condition	ng/Nm^3	ng/Nm^3 at 12% CO_2	µg/Mg feed	ng/Nm^3	ng/Nm^3 at 12% CO_2	µg/Mg feed	Control effi- ciency, %
Mass burn								
Waterwall								
ESP					0.410	0.548	2.1	
Chicago	Normal				63.0	62.5	289	
Hampton (1982)	Normal				32.0	29.8	145	
Hampton (1983)	Normal				19.6	35.1	89	
Hampton (1984)	Normal				0.532	0.67		66.5
N. Andover[a]	Normal	1.67	2				1.17	
Peekskill (4/85)	Normal				1.43	1.7		
Saugus	Normal				0.082	0.101	0.397	
Tulsa (Units 1 and 2)	Normal					0.6		
Umea, fall	Normal					0.48		
Umea, fall	Low temp					0.12		
Umea, spring	Normal							
WSH/DI/FF					0.012	0.018	0.0511	
Wurzburg	Normal							
SD/FF						0.081	0.371	
Marion County	Normal							
Refractory								
ESP					6.03	13.7		
Philadelphia (NW1)	Normal				4.83	12.3		
Philadelphia (NW2)	Normal							
CYC					1.67	2.60	20.6	
Mayport	MSW/waste oil							
Starved air								
No control device								
Cattaraugus County	Normal	0.54						
Dyersburg	Normal	0.900	1.54	6.51				
ESP					<0.175	<0.278	<11.7	
Red Wing	Normal							
RDF fired								
ESP					9.83	14.6	36	
Akron	Normal				0.413	0.522	2.57	
Albany	Normal							

[a] Outlet values which represent the average of test runs 3, 4, and 5 were used to obtain a control efficiency value for simultaneous test runs. Inlet runs 1 and 2 were not analyzed due to sampling difficulties.

TABLE 7-28. SUMMARY OF TOTAL TETRACHLORODIBENZO-p-DIOXIN EMISSIONS FROM MWC FACILITIES

Facility name	Test condition	Emissions upstream from control device: ng/Nm^3	Emissions upstream from control device: ng/Nm^3 at 12% CO_2	Emissions upstream from control device: µg/Mg feed	Emissions downstream from control device: ng/Nm^3	Emissions downstream from control device: ng/Nm^3 at 12% CO_2	Emissions downstream from control device: µg/Mg feed	Control effi- ciency, %
Mass burn								
Waterwall								
ESP								
Chicago	Normal				6.27	8.39	31.6	
Hampton (1981)	Normal				440	800	3,020	
Hampton (1982)	Normal				245	243	1,130	
Hampton (1983)	Normal				230	214	1,040	
Hampton (1984)	Normal				645	1,160	2,930	
N. Andover[a]	Normal	14.2	17		6.65	8.38		50.7
Peekskill (4/85)	Normal						11.8	
Saugus	Normal				26.9	31.9		
Tulsa (Units 1 and 2)	Normal				1.32	1.61	6.34	
Umea, fall	Normal					51.6		
Umea, fall	Low temp					64.8		
Umea, spring	Normal					<12		
WSH/DI/FF								
Quebec[b]	110	16.3	27.5		0.0			
Quebec[b]	125	44.4	72		0.0			
Quebec[b]	140	59.2	94.7		0.0			
Quebec[b]	200	24.1	39.6		0.0			
Wurzburg	Normal				1.34	1.91	5.42	
SD/FF								
Marion County	Normal					0.195	0.893	
Quebec[b]	140	32.3	46.8		0.0			
Quebec	140 & R.	48.5	77.7		0.0399	0.0639		99.9
Refractory								
ESP								
Philadelphia (NW1)	Normal				167	378		
Philadelphia (NW2)	Normal				143	365		
CYC								
Mayport	MSW/waste oil				3.57	5.56	45.2	
Starved air								
No control device								
Cattaraugus County	Normal	8.1						
Dyersburg	Normal	11.2	19.1	81				
Prince Edward Island	Normal	1.95	3.05	14				
Prince Edward Island	Long	3.18	5.09	20				
Prince Edward Island	High	0.839	1.02	4.0				
Prince Edward Island	Low	1.65	3.05	14				
ESP								
Red Wing	Normal				27.6	43.7	1,840	
RDF fired								
ESP								
Akron	Normal				174	258	636	
Albany	Normal				15.8	19.9	98.1	
Hamilton-Wentworth[c]	F/None				407	590		
Hamilton-Wentworth[d]	F/Low back				580	560		
Hamilton-Wentworth	F/Back				481	570		

(continued)

TABLE 7-28. (continued)

Facility name	Test condition	Emissions upstream from control device			Emissions downstream from control device			Control effi-ciency, %
		ng/Nm^3	ng/Nm^3 at 12% CO_2	µg/Mg feed	ng/Nm^3	ng/Nm^3 at 12% CO_2	µg/Mg feed	
Hamilton-Wentworth[c]	F/Back, low front				2,430	3,500		
Hamilton-Wentworth[c]	H/None				539	1,200		
Hamilton-Wentworth[c]	H/Low back				402	700		
CYC/ESP								
Wright Pat. AFB	Normal				2.20	3.47	21.5	

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[a] Outlet values which represent the average of test runs 3, 4, and 5 were used to obtain a control efficiency value for simultaneous test runs. Inlet runs 1 and 2 were not analyzed due to sampling difficulties.

[b] A 0.0 indicates below detection limit (values of detection limit not yet received).

[c] Average of two test runs.

[d] One test run only.

TABLE 7-29. SUMMARY OF TOTAL PENTACHLORODIBENZO-p-DIOXIN EMISSIONS FROM MWC FACILITIES

Facility name	Test condition	Emissions upstream from control device			Emissions downstream from control device			Control effi- ciency, %
		ng/Nm^3	ng/Nm^3 at 12% CO_2	µg/Mg feed	ng/Nm^3	ng/Nm^3 at 12% CO_2	µg/Mg feed	
Mass burn								
Waterwall								
ESP								
Hampton (1981)	Normal				560	1,020	3,840	
Hampton (1983)	Normal				1,200	1,120	5,440	
Hampton (1984)	Normal				1,510	2,700	6,860	
N. Andover[a]	Normal	24.2	29		9.13	11.5		60.3
Peekskill (4/85)	Normal						11.7	
Saugus	Normal				29.8	35.4		
Tulsa (Units 1 and 2)	Normal				2.44	2.99	11.7	
Umea, fall	Normal					63.6		
Umea, fall	Low temp					96		
Umea, spring	Normal					58.8		
WSH/DI/FF								
Quebec[b]	110	35.1	59.3		0.0			
Quebec[b]	125	93.6	152		0.0			
Quebec[b]	140	95.8	154		0.0			
Quebec[b]	200	62.1	102		0.0			
Wurzburg	Normal				1.78	2.54	7.21	
SD/FF								
Marion County	Normal					0.053	0.243	
Quebec[b]	140	69.1	99.9		0.0			
Quebec[b]	140 & R.	89.1	142		0.0			
Refractory								
ESP								
Philadelphia (NW1)	Normal				470	1,060		
Philadelphia (NW2)	Normal				407	1,040		
Starved air								
No control device								
Cattaraugus County	Normal	10.6						
Prince Edward Island	Normal	7.18	11.2	42				
Prince Edward Island	Long	9.58	15.3	55				
Prince Edward Island	High	5.86	7.12	23				
Prince Edward Island	Low	4.41	8.14	32				
ESP								
Red Wing	Normal				172	273	11,500	
RDF fired								
ESP								
Albany	Normal				133	168	828	
Hamilton-Wentworth[c]	F/None				336	490		
Hamilton-Wentworth[d]	F/Low back				641	620		
Hamilton-Wentworth[c]	F/Back				562	660		
Hamilton-Wentworth[c]	F/Back, low front				1,760	2,600		
Hamilton-Wentworth[c]	H/None				570	1,300		
Hamilton-Wentworth[c]	H/Low back				610	1,000		

(continued)

TABLE 7-29. (continued)

Facility name	Test condition	Emissions upstream from control device			Emissions downstream from control device			Control effi-ciency, %
		ng/Nm^3	ng/Nm^3 at 12% CO_2	µg/Mg feed	ng/Nm^3	ng/Nm^3 at 12% CO_2	µg/Mg feed	
CYC/ESP								
Wright Pat. AFB	Normal				0.370	0.584	3.6	

[a] Outlet values which represent the average of test runs 3, 4, and 5 were used to obtain a control efficiency value for simultaneous test runs. Inlet runs 1 and 2 were not analyzed due to sampling difficulties.

[b] A 0.0 indicates below detection limit (values of detection limit not yet received).

[c] Average of the test runs.

[d] One test run only.

TABLE 7-30. SUMMARY OF TOTAL HEXACHLORODIBENZO-p-DIOXIN EMISSIONS FROM MWC FACILITIES

Facility name	Test condition	Emissions upstream from control device			Emissions downstream from control device			Control effi-ciency, %
		ng/Nm^3	ng/Nm^3 at 12% CO$_2$	µg/Mg feed	ng/Nm^3	ng/Nm^3 at 12% CO$_2$	µg/Mg feed	
Mass burn								
Waterwall								
ESP								
Chicago	Normal				16.3	21.8	82.4	
Hampton (1981)	Normal				880	1,600	6,050	
Hampton (1983)	Normal				510	474	2,320	
Hampton (1984)	Normal				1,780	3,190	8,090	
N. Andover[a]	Normal	36.7	44		18.7	23.6		46.4
Peekskill (4/85)	Normal						16	
Saugus	Normal				29.1	34.6		
Tulsa (Units 1 and 2)	Normal				4.16	5.10	20	
Umea, fall	Normal					38.4		
Umea, fall	Low temp					98.4		
Umea, spring	Normal					66		
WSH/DI/FF								
Quebec	110	91.9	155		0.0383	0.0647		>99.9
Quebec[b]	125	255	414		0.0			
Quebec[b]	140	226	362		0.0			
Quebec	200	156	257		1.59	2.61		99.0
Wurzburg	Normal				2.23	3.18	9.03	
SD/FF								
Marion County	Normal					0.110	0.504	
Quebec[b]	140	185	268		0.0			
Quebec	140 & R.	251	402		0.0915	0.146		>99.9
Refractory								
ESP								
Philadelphia (NW1)	Normal				1,220	2,760		
Philadelphia (NW2)	Normal				360	919		
Starved air								
No control device								
Cattaraugus County	Normal	13.4						
Prince Edward Island	Normal	12.8	20.0	78				
Prince Edward Island	Long	13.8	22.0	80				
Prince Edward Island	High	8.22	10.0	38				
Prince Edward Island	Low	8.67	16.0	69				
ESP								
Red Wing	Normal				300	476	20,100	
RDF fired								
ESP								
Albany	Normal				113	142	701	
Hamilton-Wentworth[c]	F/None				361	520		
Hamilton-Wentworth[d]	F/Low back				478	460		
Hamilton-Wentworth[c]	F/Back				659	790		
Hamilton-Wentworth[c]	F/Back, low front				1,220	1,800		
Hamilton-Wentworth[c]	H/None				661	1,400		
Hamilton-Wentworth[c]	H/Low back				742	1,300		

(continued)

TABLE 7-30. (continued)

Facility name	Test condition	Emissions upstream from control device			Emissions downstream from control device			Control effi-ciency, %
		ng/Nm^3	ng/Nm^3 at 12% CO$_2$	µg/Mg feed	ng/Nm^3	ng/Nm^3 at 12% CO$_2$	µg/Mg feed	
CYC/ESP Wright Pat. AFB	Normal				2.50	3.95	24.3	

[a] Outlet values which represent the average of test runs 3, 4, and 5 were used to obtain a control efficiency value for simultaneous test runs. Inlet runs 1 and 2 were not analyzed due to sampling difficulties.

[b] A 0.0 indicates below detection limit (values of detection limit not yet received).

[c] Average of two test runs.

[d] One test run only.

TABLE 7-31. SUMMARY OF TOTAL HEPTACHLORODIBENZO-p-DIOXIN EMISSIONS FROM MWC FACILITIES

Facility name	Test condition	Emissions upstream from control device			Emissions downstream from control device			Control efficiency, %
		ng/Nm^{3}	ng/Nm^{3} at 12% CO$_{2}$	µg/Mg feed	ng/Nm^{3}	ng/Nm^{3} at 12% CO$_{2}$	µg/Mg feed	
Mass burn								
Waterwall								
ESP								
Chicago	Normal				7.57	10.1	38.3	
Hampton (1981)	Normal				1,060	1,930	7,320	
Hampton (1983)	Normal				160	149	725	
Hampton (1984)	Normal				1,610	2,880	7,310	
N. Andover^{a}	Normal	30	36		21.7	27.3		24.2
Peekskill (4/85)	Normal						23	
Saugus	Normal				25.3	30		
Tulsa (Units 1 and 2)	Normal				3.62	4.43	17.4	
Umea, fall	Normal					21.6		
Umea, fall	Low temp					64.8		
Umea, spring	Normal					67.2		
WSH/DI/FF								
Quebec^{b}	110	126	209		0.0			
Quebec^{b}	125	307	489		0.0			
Quebec^{b}	140	250	394		0.0			
Quebec	200	231	374		1.62	2.65		99.3
Wurzburg	Normal				3.01	4.30	12.2	
SD/FF								
Marion County	Normal					0.184	0.842	
Quebec^{b}	140	277	394		0.0			
Quebec	140 & R.	262	413		0.107	0.171		>99.9
Refractory								
ESP								
Philadelphia (NW1)	Normal				400	906		
Philadelphia (NW2)	Normal				157	401		
Starved air								
No control device								
Cattaraugus County	Normal	12.6						
Prince Edward Island	Normal	20.2	31.5	122				
Prince Edward Island	Long	17.2	27.5	103				
Prince Edward Island	High	15.9	19.3	67				
Prince Edward Island	Low	18.7	34.6	142				
ESP								
Red Wing	Normal				282	447	18,800	
RDF fired								
ESP								
Albany	Normal				103	130	642	
Hamilton-Wentworth^{c}	F/None				91.7	130		
Hamilton-Wentworth^{d}	F/Low back				509	490		
Hamilton-Wentworth	F/Back				295	510		
Hamilton-Wentworth^{c}	F/Back, low front				346	540		
Hamilton-Wentworth^{c}	H/None				234	520		
Hamilton-Wentworth^{c}	H/Low back				458	830		

(continued)

TABLE 7-31. (continued)

Facility name	Test condition	Emissions upstream from control device			Emissions downstream from control device			Control effi- ciency, %
		ng/Nm^3	ng/Nm^3 at 12% CO_2	μg/Mg feed	ng/Nm^3	ng/Nm^3 at 12% CO_2	μg/Mg feed	
CYC/ESP								
Wright Pat. AFB	Normal				18.6	29.3	181	

[a] Outlet values which represent the average of test runs 3, 4, and 5 were used to obtain a control efficiency value for simultaneous test runs. Inlet runs 1 and 2 were not analyzed due to sampling difficulties.

[b] A 0.0 indicates below detection limit (values of detection limit not yet received).

[c] Average of two test runs.

[d] One test run only.

TABLE 7-32. SUMMARY OF TOTAL OCTACHLORODIBENZO-p-DIOXIN EMISSIONS FROM MWC FACILITIES

Facility name	Test condition	Emissions upstream from control device			Emissions downstream from control device			Control effi-ciency, %
		ng/Nm^3	ng/Nm^3 at 12% CO$_2$	μg/Mg feed	ng/Nm^3	ng/Nm^3 at 12% CO$_2$	μg/Mg feed	
Mass burn								
Waterwall								
ESP								
Chicago	Normal				2.53	3.39	12.8	
Hampton (1981)	Normal				280	509	1,930	
Hampton (1983)	Normal				41.0	38.1	186	
Hampton (1984)	Normal				410	734	1,870	
N. Andover[a]	Normal	24.2	29		17.5	22		24.1
Peekskill (4/85)	Normal						37	
Saugus	Normal				31.4	37.3		
Tulsa (Units 1 and 2)	Normal				3.93	4.81	18.9	
Umea, fall	Normal					14.4		
Umea, fall	Low temp					16.8		
Umea, spring	Normal					63.6		
WSH/DI/FF								
Quebec	110	105	178		0.0585	0.0988		99.9
Quebec[b]	125	243	395		0.0			
Quebec[b]	140	204	326		0.0			
Quebec	200	174	286		0.634	1.04		99.6
Wurzburg	Normal				7.15	10.2	28.9	
SD/FF								
Marion County	Normal					0.589	2.7	
Quebec[b]	140	221	318		0.0			
Quebec[b]	140 & R.	204	327		0.0			
Refractory								
ESP								
Philadelphia (NW1)	Normal				161	365		
Philadelphia (NW2)	Normal				64.7	165		
Starved air								
No control device								
Cattaraugus County	Normal	13.7						
Prince Edward Island	Normal	28.0	43.7	172				
Prince Edward Island	Long	24.1	38.6	142				
Prince Edward Island	High	21.7	26.4	95				
Prince Edward Island	Low	34.2	63.1	259				
ESP								
Red Wing	Normal				191	302	12,700	
RDF fired								
ESP								
Albany	Normal				17.3	21.8	108	
Hamilton-Wentworth[c]	F/None				96.8	140		
Hamilton-Wentworth[d]	F/Low back				264	260		
Hamilton-Wentworth	F/Back				201	310		
Hamilton-Wentworth[c]	F/Back, low front[f]				270	410		
Hamilton-Wentworth[c]	H/None				178	400		
Hamilton-Wentworth[c]	H/Low back				437	770		

(continued)

TABLE 7-32. (continued)

Facility name	Test condition	Emissions upstream from control device			Emissions downstream from control device			Control effi-ciency, %
		ng/Nm^3	ng/Nm^3 at 12% CO_2	µg/Mg feed	ng/Nm^3	ng/Nm^3 at 12% CO_2	µg/Mg feed	
CYC/ESP Wright Pat. AFB	Normal				10.4	16.4	101	

[a] Outlet values which represent the average of test runs 3, 4, and 5 were used to obtain a control efficiency value for simultaneous test runs. Inlet runs 1 and 2 were not analyzed due to sampling difficulties.

[b] A 0.0 indicates below detection limit (values of detection limit not yet received).

[c] Average of two test runs.

[d] One test run only.

TABLE 7-33. SUMMARY OF TETRA- THROUGH OCTACHLORODIBENZO-p-DIOXIN EMISSIONS FROM MWC FACILITIES

Facility name	Test condition	Emissions upstream from control device			Emissions downstream from control device			Control effi-ciency, %
		ng/Nm^3	ng/Nm^3 at 12% CO_2	µg/Mg feed	ng/Nm^3	ng/Nm^3 at 12% CO_2	µg/Mg feed	
Mass burn								
Waterwall								
ESP								
Hampton (1981)	Normal				3,220	5,850	22,100	
Hampton (1983)	Normal				2,140	1,990	9,700	
Hampton (1984)	Normal				5,950	10,700	27,100	
N. Andover^a	Normal	129	155		73.6	92.8		40.1
Peekskill (4/85)	Normal						966	
Saugus	Normal				143	169		
Tulsa (Units 1 and 2)	Normal				15.5	18.9	74.5	
Umea, fall	Normal					190		
Umea, fall	Low temp					341		
Umea, spring	Normal					268		
WSH/DI/FF								
Quebec	110	376	636		0.0974	0.165		>99.9
Quebec^b	125	948	1,540		0.0			
Quebec^b	140	840	1,340		0.0			
Quebec	200	650	1,070		3.85	6.35		99.4
Wurzburg	Normal				15.5	22.1	62.7	
SD/FF								
Marion County	Normal					1.13	5.17	
Quebec^b	140	788	1,140		0.0			
Quebec	140 & R.	860	1,370		0.238	0.381		>99.9
Refractory								
ESP								
Philadelphia (NW1)	Normal				2,370	5,370		
Philadelphia (NW2)	Normal				1,100	2,890		
Starved air								
No control device								
Cattaraugus County	Normal	58.4						
Prince Edward Island	Normal	69.8	109	428				
Prince Edward Island	Long	68.2	109	400				
Prince Edward Island	High	51.9	63.1	228				
Prince Edward Island	Low	67.7	125	515				
ESP								
Red Wing	Normal				976	1,540	65,200	
RDF fired								
ESP								
Albany	Normal				381	482	2,370	
Hamilton-Wentworth^c	F/None				1,292	1,870		
Hamilton-Wentworth^d	F/Low back				2,470	2,390		
Hamilton-Wentworth	F/Back				2,200	2,840		
Hamilton-Wentworth^c	F/Back, low front				6,030	8,850		
Hamilton-Wentworth^c	H/None				2,180	4,820		
Hamilton-Wentworth^c	H/Low back				2,650	4,600		

(continued)

TABLE 7-33. (continued)

		Emissions upstream from control device			Emissions downstream from control device			
Facility name	Test condition	ng/Nm^3	ng/Nm^3 at 12% CO_2	μg/Mg feed	ng/Nm^3	ng/Nm^3 at 12% CO_2	μg/Mg feed	Control effi-ciency, %
CYC/ESP								
Wright Pat. AFB	Normal				40.8	53.7	398	

[a] Outlet values which represent the average of test runs 3, 4, and 5 were used to obtain a control efficiency value for simultaneous test runs. Inlet runs 1 and 2 were not analyzed due to sampling difficulties.

[b] A 0.0 indicates below detection limit (values of detection limit not yet received).

[c] Average of two test runs.

[d] One test run only.

TABLE 7-34. SUMMARY OF TOTAL MEASURED CHLORODIBENZO-p-DIOXIN EMISSIONS FROM MWC FACILITIES

		Emissions upstream from control device			Emissions downstream from control device			
Facility name	Test condition	ng/Nm^3	ng/Nm^3 at 12% CO_2	µg/Mg feed	ng/Nm^3	ng/Nm^3 at 12% CO_2	µg/Mg feed	Control effi-ciency, %
Mass burn								
Waterwall								
ESP								
Chicago[a]	Normal				32.7	43.7	168	
Hampton (1981)[b]	Normal				3,220	5,850	22,100	
Hampton (1982)[c]	Normal				245	243	1,130	
Hampton (1983)[b]	Normal				2,140	1,990	9,700	
Hampton (1984)[b]	Normal				5,950	10,700	27,100	
N. Andover[d]	Normal	141	169		78.9	99.5		41.1
Peekskill (4/85)[b]	Normal						966	
Saugus[b]	Normal				143	169		
Tulsa (Units 1 and 2)[b]	Normal				15.5	18.9	74.5	
Umea, fall[b]	Normal					190		
Umea, fall[b]	Low temp					341		
Umea, spring[b]	Normal					268		
WSH/DI/FF								
Quebec[b]	110	376	636		0.0974	0.165		>99.9
Quebec[e,f]	125	948	1,540		0.0			
Quebec[e,f]	140	840	1,340		0.0			
Quebec[e]	200	650	1,070		3.85	6.35		99.4
Wurzburg[b]	Normal				15.5	22.1	62.7	
SD/FF								
Marion County[b]	Normal					1.13	5.17	
Quebec[e,f]	140	788	1,140		0.0			
Quebec[e]	140 & R.	860	1,370		0.239	0.383		>99.9
Refractory								
ESP								
Philadelphia (NW1)[b]	Normal				2,370	5,370		
Philadelphia (NW2)[b]	Normal				1,100	2,890		
CYC								
Mayport[c]	MSW/waste oil				3.57	5.56	45.2	
EGB								
Pittsfield[d]	Experimental	53.6						
Starved air								
No control device								
Cattaraugus County[b]	Normal	58.4						
Dyersburg[c]	Normal	11.2	19.1	81				
Prince Edward Island[b]	Normal	69.8	109	428				
Prince Edward Island[b]	Long	68.2	109	400				
Prince Edward Island[b]	High	51.9	63.1	228				
Prince Edward Island[b]	Low	67.7	125	515				
ESP								
Red Wing[b]	Normal				976	1,540	65,200	
RDF fired								
ESP								
Akron[c]	Normal				174	258	636	
Albany[b]	Normal				381	482	2,370	
Hamilton-Wentworth[b,g]	F/None				1,292	1,870		
Hamilton-Wentworth[b,h]	F/Low back				2,470	2,390		

(continued)

TABLE 7-34. (continued)

Facility name	Test condition	Emissions upstream from control device ng/Nm^3	ng/Nm^3 at 12% CO_2	µg/Mg feed	Emissions downstream from control device ng/Nm^3	ng/Nm^3 at 12% CO_2	µg/Mg feed	Control effi- ciency, %
Hamilton-Wentworth[b]	F/Back				2,200	2,840		
Hamilton-Wentworth[b g]	F/Back, low front				6,030	8,850		
Hamilton-Wentworth[b g]	H/None				2,180	4,820		
Hamilton-Wentworth[b g]	H/Low back				2,650	4,600		
CYC/ESP								
Wright Pat. AFB[b]	Normal				40.8	53.7	398	

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[a] Sum of tetra- through octachlorodibenzo-p-dioxin without penta.
[b] Sum of tetra- through octachlorodibenzo-p-dioxin.
[c] Tetrachlorodibenzo-p-dioxin only.
[d] Outlet values which represent the average of test runs 3, 4, and 5 were used to obtain a control efficiency value for
[e] simultaneous test runs. Inlet runs 1 and 2 were not analyzed due to sampling difficulties.
Presented as polychlorodibenzo-p-dioxin in test report.
[f] A 0.0 indicates below detection limit (values of detection limit not yet received).
[g] Average of two test runs.
[h] One test run only.

Isomer-specific PCDD in SI units

7-35 Summary of 2,3,7,8-Substituted and Total Tetrachlorodibenzo-p-dioxin Emissions from MWC Facilities

7-36 Summary of 2,3,7,8-Substituted and Total Pentachlorodibenzo-p-dioxin Emissions from MWC Facilities

7-37 Summary of 2,3,7,8-Substituted and Total Hexachlorodibenzo-p-dioxin Emissions from MWC Facilities

7-38 Summary of 2,3,7,8-Substituted and Total Heptachlorodibenzo-p-dioxin Emissions from MWC Facilities

TABLE 7-35. SUMMARY OF 2,3,7,8-SUBSTITUTED AND TOTAL TETRACHLORODIBENZO-P-DIOXIN EMISSIONS FROM MWC FACILITIES

Facility name	Test condition	Emissions upstream from control device		Emissions downstream from control device	
		2,3,7,8-TCDD, ng/Nm^3 at 12% CO_2	Total TCDD, ng/Nm^3 at 12% CO_2	2,3,7,8-TCDD, ng/Nm^3 at 12% CO_2	Total TCDD, ng/Nm^3 at 12% CO_2
Mass burn					
Waterwall					
ESP					
Chicago	Normal			0.548	8.39
Hampton (1982)	Normal			62.5	243
Hampton (1983)	Normal			29.8	214
Hampton (1984)	Normal			35.1	1,160
N. Andover	Normal	2	17	0.67	8.38
Saugus	Normal			1.7	31.9
Tulsa (Units 1 and 2)	Normal			0.101	1.61
Umea, fall	Normal			0.6	51.6
Umea, fall	Low temp			0.48	64.8
Umea, spring	Normal			0.12	<12
WSH/DI/FF					
Wurzburg	Normal			0.018	1.91
SD/FF					
Marion County	Normal			0.081	0.195
Refractory					
ESP					
Philadelphia (NW1)	Normal			13.7	378
Philadelphia (NW2)	Normal			12.3	365
CYC					
Mayport	MSW/waste oil			2.60	5.56
Starved air					
No control device					
Cattaraugus County[a]	Normal	0.54	8.1		
Dyersburg	Normal	1.54	19.1		
ESP					
Red Wing	Normal			<0.278	43.7

(continued)

TABLE 7-35. (continued)

Emissions					
Emissions upstream from control device		downstream from control device			
Test Facility name	2,3,7,8-TCDD, condition	Total TCDD, ng/Nm^3 at 12% CO_2	2,3,7,8-TCDD, ng/Nm^3 at 12% CO_2	Total TCDD, ng/Nm^3 at 12% CO_2	ng/Nm^3 at 12% CO_2
RDF fired					
ESP					
Akron	Normal			14.6	258
Albany	Normal			0.522	19.9

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[a] Not corrected to 12 percent CO_2.

TABLE 7-36. SUMMARY OF 2,3,7,8-SUBSTITUTED AND TOTAL PENTACHLORODIBENZO-P-DIOXIN EMISSIONS FROM MWC FACILITIES

Facility name	Test condition	Emissions upstream from control device		Emissions downstream from control device	
		1,2,3,7,8-PeCDD, ng/Nm^3 at 12% CO_2	Total PeCDD, ng/Nm^3 at 12% CO_2	1,2,3,7,8-PeCDD, ng/Nm^3 at 12% CO_2	Total PeCDD, ng/Nm^3 at 12% CO_2
Mass burn					
Waterwall					
ESP					
N. Andover	Normal	1	29	1.32	11.5
Saugus	Normal			3.4	35.4
Tulsa (Units 1 and 2)	Normal			0.19	2.99
Umea, fall	Normal			3.0	64
Umea, fall	Low temp			3.8	96
Umea, spring	Normal			2.9	59
WSH/DI/FF					
Wurzburg	Normal			0.20	2.54
SD/FF					
Marion County	Normal			0.009	0.053
Refractory					
ESP					
Philadelphia (NW1)	Normal			82	1,060
Philadelphia (NW2)	Normal			91	1,040
Starved air					
ESP					
Red Wing	Normal			12.8	273

TABLE 7-37. SUMMARY OF 2,3,7,8-SUBSTITUTED AND TOTAL HEXACHLORODIBENZO-P-DIOXIN EMISSIONS FROM MWC FACILITIES

		Emissions upstream from control device				Emissions downstream from control device			
Facility name	Test condition	1,2,3,4,7,8-HxCDD, ng/Nm^3 at 12% CO_2	1,2,3,6,7,8-HxCDD, ng/Nm^3 at 12% CO_2	1,2,3,7,8,9-HxCDD, ng/Nm^3 at 12% CO_2	Total HxCDD, ng/Nm^3 at 12% CO_2	1,2,3,4,7,8-HxCDD, ng/Nm^3 at 12% CO_2	1,2,3,6,7,8-HxCDD, ng/Nm^3 at 12% CO_2	1,2,3,7,8,9-HxCDD, ng/Nm^3 at 12% CO_2	Total HxCDD, ng/Nm^3 at 12% CO_2
Mass burn									
Waterwall									
ESP									
N. Andover	Normal	1	3	2	44	1.41	2.11	1.49	23.6
Saugus	Normal					1.9	3.2	0.0	34.6
Tulsa (Units 1 and 2)	Normal					0.15	0.37	0.00	5.10
Umea, fall	Normal					1.9	4.4	1.6	38
Umea, fall	Low temp					6.1	11	4.6	98
Umea, spring	Normal					2.8	7.0	2.4	66
WSH/DI/FF									
Wurzburg	Normal					0.08	0.19	0.12	3.18
SD/FF									
Marion County	Normal					0.007	0.008	0.008	0.110
Refractory									
ESP									
Philadelphia (MW1)	Normal					300			2,760
Philadelphia (MW2)	Normal					115			919
Starved air									
ESP									
Red Wing	Normal					17.3	48.2	69.0	475

TABLE 7-38. SUMMARY OF 2,3,7,8-SUBSTITUTED AND TOTAL HEPTACHLORODIBENZO-P-DIOXIN EMISSIONS FROM MWC FACILITIES

Facility name	Test condition	Emissions upstream from control device		Emissions downstream from control device	
		1,2,3,4,6,7,8-HpCDD ng/Nm^3 at 12% CO_2	Total HpCDD, ng/Nm^3 at 12% CO_2	1,2,3,4,6,7,8-HpCDD, ng/Nm^3 at 12% CO_2	Total HpCDD, ng/Nm^3 at 12% CO_2
Mass burn					
Waterwall					
ESP					
Tulsa (Units 1 and 2)	Normal			2.20	4.43
WSH/DI/FF					
Wurzburg	Normal			2.20	4.30
SD/FF					
Marion County	Normal			0.138	0.184
Refractory					
ESP					
Philadelphia (NW1)	Normal			458	906
Philadelphia (NW2)	Normal			201	401
Starved air					
ESP					
Red Wing	Normal			225	447

PCDF in SI units

7-39 Summary of 2,3,7,8-Tetrachlorodibenzofuran Emissions From MWC Facilities

7-40 Summary of Total Tetrachlorodibenzofuran Emissions From MWC Facilities

7-41 Summary of Total Pentachlorodibenzofuran Emissions From MWC Facilities

7-42 Summary of Total Hexachlorodibenzofuran Emissions From MWC Facilities

7-43 Summary of Total Heptachlorodibenzofuran Emissions From MWC Facilities

7-44 Summary of Total Octachlorodibenzofuran Emissions From MWC Facilities

7-45 Summary of Tetra- Through Octachlorodibenzofuran Emissions From MWC Facilities

7-46 Summary of Total Measured Chlorodibenzofuran Emissions From MWC Facilities

TABLE 7-39. SUMMARY OF 2,3,7,8-TETRACHLORODIBENZOFURAN EMISSIONS FROM MWC FACILITIES

Facility name	Test condition	Emissions upstream from control device			Emissions downstream from control device			Control efficiency, %
		ng/Nm^3	ng/Nm^3 at 12% CO_2	µg/Mg feed	ng/Nm^3	ng/Nm^3 at 12% CO_2	µg/Mg feed	
Mass burn								
Waterwall								
ESP								
Hampton (1982)	Normal				73.0	72.4	335	
Hampton (1984)	Normal				250	448	1,130	
N. Andover[a] [b]	Normal	9.17	11		12.9	16.3		
Peekskill (4/85)	Normal						8.95	
Saugus	Normal				19.6	23.3		
Tulsa (Units 1 and 2)	Normal				2.37	2.91	11.4	
Umea, fall	Normal					3		
Umea, fall	Low temp					3.12		
Umea, spring	Normal					0.96		
WSH/DI/FF								
Wurzburg	Normal				0.180	0.250	0.710	
SD/FF								
Marion County	Normal					0.168	0.769	
Refractory								
ESP								
Philadelphia (NW1)	Normal				25.3	57.3		
Philadelphia (NW2)	Normal				13.2	33.7		
CYC								
Mayport	MSW/waste oil				10.3	16.0	127	
Starved air								
No control device								
Cattaraugus County	Normal	2.70						
ESP								
Red Wing	Normal				36.9	58.5	2,470	
RDF fired								
ESP								
Albany	Normal				2.13	2.69	13.3	

[a] Outlet values which represent the average of test runs 3, 4, and 5 were used to obtain a control efficiency value for simultaneous test runs. Inlet runs 1 and 2 were not analyzed due to sampling difficulties.

[b] An apparent increase in concentration occurred across the control device; however, no reason for this increase was indicated in the test reports.

TABLE 7-40. SUMMARY OF TOTAL TETRACHLORODIBENZOFURAN EMISSIONS FROM MWC FACILITIES

Facility name	Test condition	Emissions upstream from control device			Emissions downstream from control device			Control effi-ciency, %
		ng/Nm^3	ng/Nm^3 at 12% CO_2	µg/Mg feed	ng/Nm^3	ng/Nm^3 at 12% CO_2	µg/Mg feed	
Mass burn								
Waterwall								
ESP								
Chicago	Normal				89.7	120	453	
Hampton (1981)	Normal				2,510	4,560	17,200	
Hampton (1982)	Normal				385	382	1,770	
Hampton (1983)	Normal				1,100	1,020	4,990	
Hampton (1984)	Normal				1,920	3,440	8,720	
N. Andover[a,b]	Normal	35.8	43		49.2	62		
Peekskill (4/85)	Normal						124	
Saugus	Normal				153	182		
Tulsa (Units 1 and 2)	Normal				5.97	7.31	28.7	
Umea, fall	Normal					103		
Umea, fall	Low temp					104		
Umea, spring	Normal					22.8		
WSH/DI/FF								
Quebec[c]	110	61.0	103		0.0			
Quebec[c]	125	183	297		0.0			
Quebec[c]	140	220	352		0.0			
Quebec	200	84.3	138		0.0317	0.0521		>99.9
Wurzburg	Normal				6.73	9.60	27.2	
SD/FF								
Marion County	Normal					0.322	1.47	
Quebec[c]	140	131	189		0.0			
Quebec	140 & R.	158	252		0.0798	0.128		>99.9
Refractory								
ESP								
Philadelphia (NW1)	Normal				483	1,090		
Philadelphia (NW2)	Normal				291	743		
CYC								
Mayport	MSW/waste oil				21.0	32.8	261	
Starved air								
No control device								
Cattaraugus County	Normal	120						
Dyersburg	Normal	72.5	124	525				
Prince Edward Island	Normal	15.0	23.4	93				
Prince Edward Island	Long	15.3	24.4	89				
Prince Edward Island	High	10.0	12.2	43				
Prince Edward Island	Low	7.15	13.2	56				
ESP								
Red Wing	Normal				217	345	14,600	

(continued)

TABLE 7-40. (continued)

Facility name	Test condition	Emissions upstream from control device ng/Nm^3	Emissions upstream from control device ng/Nm^3 at 12% CO_2	Emissions upstream from control device µg/Mg feed	Emissions downstream from control device ng/Nm^3	Emissions downstream from control device ng/Nm^3 at 12% CO_2	Emissions downstream from control device µg/Mg feed	Control effi-ciency, %
RDF fired								
ESP								
Akron	Normal				458	679	1,680	
Albany	Normal				37.1	46.9	231	
Hamilton-Wentworth[d]	F/None				2,450	3,600		
Hamilton-Wentworth[e]	F/Low back				2,610	3,500		
Hamilton-Wentworth[d]	F/Back				3,610	3,100		
Hamilton-Wentworth[d]	F/Back, low front				4,280	5,800		
Hamilton-Wentworth[d]	H/None				1,860	4,200		
Hamilton-Wentworth[d]	H/Low back				1,310	2,300		
CYC/ESP								
Wright Pat. AFB	Normal				20.1	31.7	196	

[a] Outlet values which represent the average of test runs 3, 4, and 5 were used to obtain a control efficiency value for simultaneous test runs. Inlet runs 1 and 2 were not analyzed due to sampling difficulties.

[b] An apparent increase in concentration occurred across the control device; however, no reason for this increase was indicated in the test reports.

[c] A 0.0 indicates below detection limit (values of detection limit not yet received).

[d] Average of two test runs.

[e] One test run only.

TABLE 7-41. SUMMARY OF TOTAL PENTACHLORODIBENZOFURAN EMISSIONS FROM MWC FACILITIES

Facility name	Test condition	Emissions upstream from control device			Emissions downstream from control device			Control effi-ciency, %
		ng/Nm^3	ng/Nm^3 at 12% CO$_2$	µg/Mg feed	ng/Nm^3	ng/Nm^3 at 12% CO$_2$	µg/Mg feed	
Mass burn								
Waterwall								
ESP								
Hampton (1981)	Normal				1,010	1,840	6,940	
Hampton (1983)	Normal				6,200	5,770	28,100	
Hampton (1984)	Normal				2,580	4,620	11,700	
N. Andover^{a,b}	Normal	15	18		26.3	33.2		
Peekskill (4/85)	Normal						72.6	
Saugus	Normal				89.2	106		
Tulsa (Units 1 and 2)	Normal				2.72	3.34	13.1	
Umea, fall	Normal					116		
Umea, fall	Low temp					132		
Umea, spring	Normal					51.6		
WSH/DI/FF								
Quebec^c	110	55.2	93.3		0.0			
Quebec^c	125	154	250		0.0			
Quebec^c	140	172	275		0.0			
Quebec	200	137	226		0.0137	0.0521		>99.9
Wurzburg	Normal				6.56	9.26	26.3	
SD/FF								
Marion County	Normal					0.044	0.201	
Quebec^c	140	122	176		0.0			
Quebec	140 & R.	138	222		0.0931	0.148		99.9
Refractory								
ESP								
Philadelphia (NW1)	Normal				534	1,210		
Philadelphia (NW2)	Normal				403	1,030		
Starved air								
No control device								
Cattaraugus County	Normal	55.1						
Prince Edward Island	Normal	23.5	36.6	145				
Prince Edward Island	Long	27.3	43.7	157				
Prince Edward Island	High	19.2	23.4	81				
Prince Edward Island	Low	11.6	21.4	88				
ESP								
Red Wing	Normal				282	447	18,800	
RDF fired								
ESP								
Albany	Normal				30.4	38.4	189	
Hamilton-Wentworth^d	F/None				1,690	2,500		
Hamilton-Wentworth^e	F/Low back				3,030	2,900		
Hamilton-Wentworth$_d$	F/Back				2,690	4,000		
Hamilton-Wentworth^d	F/Back, low front				3,580	4,900		
Hamilton-Wentworth^d	H/None				1,320	2,900		
Hamilton-Wentworth^d	H/Low back				1,480	2,600		

(continued)

TABLE 7-41. (continued)

Facility name	Test condition	Emissions upstream from control device ng/Nm^3	 ng/Nm^3 at 12% CO_2	 µg/Mg feed	Emissions downstream from control device ng/Nm^3	 ng/Nm^3 at 12% CO_2	 µg/Mg feed	Control effi-ciency, %
CYC/ESP								
Wright Pat. AFB	Normal				6.97	11.0	67.9	

[a] Outlet values which represent the average of test runs 3, 4, and 5 were used to obtain a control efficiency value for simultaneous test runs. Inlet runs 1 and 2 were not analyzed due to sampling difficulties.

[b] An apparent increase in concentration occurred across the control device; however, no reason for this increase was indicated in the test reports.

[c] A 0.0 indicates below detection limit (values of detection limit not yet received).

[d] Average of two test runs.

[e] One test run only.

TABLE 7-42. SUMMARY OF TOTAL HEXACHLORODIBENZOFURAN EMISSIONS FROM MWC FACILITIES

Facility name	Test condition	Emissions upstream from control device ng/Nm³	Emissions upstream from control device ng/Nm³ at 12% CO_2	Emissions upstream from control device µg/Mg feed	Emissions downstream from control device ng/Nm³	Emissions downstream from control device ng/Nm³ at 12% CO_2	Emissions downstream from control device µg/Mg feed	Control effi-ciency, %
Mass burn								
Waterwall								
ESP								
Chicago	Normal				62.0	82.9	313	
Hampton (1981)	Normal				1,200	2,180	8,230	
Hampton (1983)	Normal				700	651	3,180	
Hampton (1984)	Normal				2,220	3,980	10,100	
N. Andover[a,b]	Normal	9.17	11		17.8	22.4		
Peekskill (4/85)	Normal						74.9	
Saugus	Normal				58.5	69.5		
Tulsa (Units 1 and 2)	Normal				1.49	1.82	7.16	
Umea, fall	Normal					39.6		
Umea, fall	Low temp					60		
Umea, spring	Normal					51.6		
WSH/DI/FF								
Quebec[c]	110	37.6	63.7		0.0			
Quebec[c]	125	156	252		0.0			
Quebec[c]	140	151	240		0.0			
Quebec	200	69.1	114		0.0317	0.521		>99.9
Wurzburg	Normal				4.23	6.04	17.1	
SD/FF								
Marion County	Normal					0.013	0.0595	
Quebec[c]	140	112	163		0.0			
Quebec	140 & R.	139	224		0.0931	0.148		99.9
Refractory								
ESP								
Philadelphia (NW1)	Normal				1,240	2,810		
Philadelphia (NW2)	Normal				313	799		
Starved air								
No control device								
Cattaraugus County	Normal	20.7						
Prince Edward Island	Normal	28.7	44.8	175				
Prince Edward Island	Long	31.1	49.8	179				
Prince Edward Island	High	26.7	32.5	113				
Prince Edward Island	Low	15.4	28.5	118				
ESP								
Red Wing	Normal				301	478	20,200	
RDF fired								
ESP								
Albany	Normal				6.53	8.25	40.7	
Hamilton-Wentworth[d]	F/None				829	1,200		
Hamilton-Wentworth[e]	F/Low back				1,170	1,100		
Hamilton-Wentworth[d]	F/Back				1,310	1,700		
Hamilton-Wentworth[d]	F/Back, low front				1,160	1,600		
Hamilton-Wentworth[d]	H/None				895	2,000		
Hamilton-Wentworth[d]	H/Low back				936	1,600		

(continued)

TABLE 7-42. (continued)

Facility name	Test condition	Emissions upstream from control device ng/Nm^3	 ng/Nm^3 at 12% CO_2	 µg/Mg feed	Emissions downstream from control device ng/Nm^3	 ng/Nm^3 at 12% CO_2	 µg/Mg feed	Control effi-ciency, %
CYC/ESP Wright Pat. AFB	Normal				11.4	18.0	111	

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[a] Outlet values which represent the average of test runs 3, 4, and 5 were used to obtain a control efficiency value for simultaneous test runs. Inlet runs 1 and 2 were not analyzed due to sampling difficulties.
[b] An apparent increase in concentration occurred across the control device; however, no reason for this increase was indicated in the test reports.
[c] A 0.0 indicates below detection limit (values of detection limit not yet received).
[d] Average of two test runs.
[e] One test run only.

TABLE 7-43. SUMMARY OF TOTAL HEPTACHLORODIBENZOFURAN EMISSIONS FROM MWC FACILITIES

Facility name	Test condition	Emissions upstream from control device			Emissions downstream from control device			Control effi- ciency, %
		ng/Nm^3	ng/Nm^3 at 12% CO_2	µg/Mg feed	ng/Nm^3	ng/Nm^3 at 12% CO_2	µg/Mg feed	
Mass burn								
Waterwall								
ESP								
Chicago	Normal				7.47	9.99	37.6	
Hampton (1981)	Normal				1,190	2,160	8,160	
Hampton (1983)	Normal				200	186	907	
Hampton (1984)	Normal				1,430	2,560	6,500	
N. Andover[a,b]	Normal	8.33	10		47.2	59.5		
Peekskill (4/85)	Normal						43.6	
Saugus	Normal				30.5	36.2		
Tulsa (Units 1 and 2)	Normal				1.92	2.35	9.24	
Umea, fall	Normal					40.8		
Umea, fall	Low temp					80.4		
Umea, spring	Normal					58.8		
WSH/DI/FF								
Quebec[c]	110	31.8	53.8		1.47	2.49		95.4
Quebec[c]	125	107	174		0.0			
Quebec	140	99.8	160		0.645	1.03		99.4
Quebec	200	46.9	77.1		0.671	1.11		98.6
Wurzburg	Normal				1.46	2.08	5.90	
SD/FF								
Marion[c] County	Normal					0.008	0.0366	
Quebec[c]	140	84.9	123		0.0			
Quebec	140 & R.	104	166		0.325	0.522		99.7
Refractory								
ESP								
Philadelphia (NW1)	Normal				323	731		
Philadelphia (NW2)	Normal				104	266		
Starved air								
No control device								
Cattaraugus County	Normal	4.0						
Prince Edward Island	Normal	21.5	33.6	133				
Prince Edward Island	Long	21.6	34.6	127				
Prince Edward Island	High	20.9	25.4	90				
Prince Edward Island	Low	15.4	28.5	118				
ESP								
Red Wing	Normal				266	422	17,800	
RDF fired								
ESP								
Albany	Normal				2.12	2.68	13.2	
Hamilton-Wentworth[d]	F/None				25.4	36		
Hamilton-Wentworth[e]	F/Low back				895	870		
Hamilton-Wentworth[d]	F/Back				234	270		
Hamilton-Wentworth[d]	F/Back, low front				178	290		
Hamilton-Wentworth[d]	H/None				50.8	110		
Hamilton-Wentworth[d]	H/Low back				112	210		

(continued)

TABLE 7-43. (continued)

Facility name	Test condition	Emissions upstream from control device			Emissions downstream from control device			Control effi-ciency, %
		ng/Nm^3	ng/Nm^3 at 12% CO$_2$	µg/Mg feed	ng/Nm^3	ng/Nm^3 at 12% CO$_2$	µg/Mg feed	
CYC/ESP Wright Pat. AFB	Normal				41.7	65.8	406	

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[a] Outlet values which represent the average of test runs 3, 4, and 5 were used to obtain a control efficiency value for simultaneous test runs. Inlet runs 1 and 2 were not analyzed due to sampling difficulties.

[b] An apparent increase in concentration occurred across the control device; however, no reason for this increase was indicated in the test reports.

[c] A 0.0 indicates below detection limit (values of detection limit not yet received).

[d] Average of two test runs.

[e] One test run only.

TABLE 7-44. SUMMARY OF TOTAL OCTACHLORODIBENZOFURAN EMISSIONS FROM MWC FACILITIES

Facility name	Test condition	Emissions upstream from control device ng/Nm^3	 ng/Nm^3 at 12% CO_2	 µg/Mg feed	Emissions downstream from control device ng/Nm^3	 ng/Nm^3 at 12% CO_2	 µg/Mg feed	Control effi- ciency, %
Mass burn								
Waterwall								
ESP								
Chicago	Normal				0.600	0.803	3.03	
Hampton (1981)	Normal				78.0	142	536	
Hampton (1983)	Normal				14.0	13.0	63.5	
Hampton (1984)	Normal				110	197	500	
N. Andover^{a,b}	Normal	2.5	3		51.7	65.1		
Peekskill (4/85)	Normal						1.6	
Saugus	Normal				14.9	17.7		
Tulsa (Units 1 and 2)	Normal				0.577	0.706	2.78	
Umea, fall	Normal					12		
Umea, fall	Low temp					27.6		
Umea, spring	Normal					39.6		
WSH/DI/FF								
Quebec^c	110	11.7	19.7		0.0			
Quebec^c	125	35.0	56.8		0.0			
Quebec^c	140	23.3	37.2		0.0			
Quebec^c	200	19.6	32.3		0.0			
Wurzburg	Normal				0.617	0.88	2.50	
SD/FF								
Marion County	Normal					0.036	0.165	
Quebec^c	140	26.6	38.5		0.0			
Quebec^c	140 & R.	27.3	43.6		0.0			
Refractory								
ESP								
Philadelphia (NW1)	Normal				21.0	47.5		
Philadelphia (NW2)	Normal				12.3	31.4		
Starved air								
No control device								
Cattaraugus County	Normal	0.070						
Prince Edward Island	Normal	3.91	6.10	23				
Prince Edward Island	Long	3.82	6.10	23				
Prince Edward Island	High	2.51	3.05	12				
Prince Edward Island	Low	3.86	7.12	31				
ESP								
Red Wing	Normal				48.2	76.3	3,220	
RDF fired								
ESP								
Hamilton-Wentworth^d	F/None				15.3	23		
Hamilton-Wentworth^e	F/Low back				173	170		
Hamilton-Wentworth^d	F/Back				35.6	42		
Hamilton-Wentworth^d	F/Back, low front				35.6	52		
Hamilton-Wentworth^d	H/None				40.7	90		
Hamilton-Wentworth^d	H/Low back				108	200		

(continued)

TABLE 7-44. (continued)

		Emissions upstream from control device			Emissions downstream from control device			
Facility name	Test condition	ng/Nm^3	ng/Nm^3 at 12% CO$_2$	µg/Mg feed	ng/Nm^3	ng/Nm^3 at 12% CO$_2$	µg/Mg feed	Control effi-ciency, %
CYC/ESP Wright Pat. AFB	Normal				5.37	8.48	52.3	

[a] Outlet values which represent the average of test runs 3, 4, and 5 were used to obtain a control efficiency value for simultaneous test runs. Inlet runs 1 and 2 were not analyzed due to sampling difficulties.

[b] An apparent increase in concentration occurred across the control device; however, no reason for this increase was indicated in the test reports.

[c] A 0.0 indicates below detection limit (values of detection limit not yet received).

[d] Average of two test runs.

[e] One test run only.

TABLE 7-45. SUMMARY OF TETRA- THROUGH OCTACHLORODIBENZOFURAN EMISSIONS FROM MWC FACILITIES

		Emissions upstream from control device			Emissions downstream from control device			
Facility name	Test condition	ng/Nm^3	ng/Nm^3 at 12% CO_2	µg/Mg feed	ng/Nm^3	ng/Nm^3 at 12% CO_2	µg/Mg feed	Control efficiency, %
Mass burn								
Waterwall								
ESP								
Hampton (1981)	Normal				5,990	10,900	41,200	
Hampton (1983)	Normal				8,210	7,640	37,300	
Hampton (1984)	Normal				8,260	14,800	37,500	
N. Andover[a,b]	Normal	70.8	85		192	242		
Peekskill (4/85)	Normal						317	
Saugus	Normal				346	411		
Tulsa (Units 1 and 2)	Normal				12.7	15.5	61	
Umea, fall	Normal					312		
Umea, fall	Low temp					404		
Umea, spring	Normal					224		
WSH/DI/FF								
Quebec	110	197	334		1.47	2.49		99.3
Quebec[c]	125	635	1,030		0.0			
Quebec	140	665	1,070		0.645	1.03		99.9
Quebec	200	357	588		0.767	1.26		99.8
Wurzburg	Normal				19.6	27.9	79.2	
SD/FF								
Marion County	Normal					0.423	1.94	
Quebec[c]	140	476	689		0.0			
Quebec	140 & R.	568	903		0.592	0.947		99.9
Refractory								
ESP								
Philadelphia (NW1)	Normal				2,600	5,890		
Philadelphia (NW2)	Normal				1,100	2,870		
Starved air								
No control device								
Cattaraugus County	Normal	200						
Prince Edward Island	Normal	92.3	144	569				
Prince Edward Island	Long	99.4	159	574				
Prince Edward Island	Low	79.5	96.6	340				
Prince Edward Island	Low	53.5	98.7	411				
ESP								
Red Wing	Normal				1,110	1,770	74,400	
RDF fired								
ESP								
Hamilton-Wentworth[d]	F/None				5,010	7,360		
Hamilton-Wentworth[e]	F/Low back				8,880	8,540		
Hamilton-Wentworth	F/Back				6,880	9,110		
Hamilton-Wentworth[d]	F/Back, low front				9,230	12,600		
Hamilton-Wentworth[d]	H/None				4,170	9,300		
Hamilton-Wentworth[d]	H/Low back				2,640	6,910		

(continued)

TABLE 7-45. (continued)

Facility name	Test condition	Emissions upstream from control device			Emissions downstream from control device			Control effi- ciency, %
		ng/Nm^3	ng/Nm^3 at 12% CO_2	µg/Mg feed	ng/Nm^3	ng/Nm^3 at 12% CO_2	µg/Mg feed	
CYC/ESP Wright Pat. AFB	Normal				85.6	135	1,010	

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[a] Outlet values which represent the average of test runs 3, 4, and 5 were used to obtain a control efficiency value for simultaneous test runs. Inlet runs 1 and 2 were not analyzed due to sampling difficulties.

[b] An apparent increase in concentration occurred across the control device; however, no reason for this increase was indicated in the test reports.

[c] A 0.0 indicates below detection limit (values of detection limit not yet received).

[d] Average of two test runs.

[e] One test run only.

TABLE 7-46. SUMMARY OF TOTAL MEASURED CHLORODIBENZOFURAN EMISSIONS FROM MWC FACILITIES

Facility name	Test condition	Emissions upstream from control device			Emissions downstream from control device			Control effi-ciency, %
		ng/Nm^3	ng/Nm^3 at 12% CO_2	µg/Mg feed	ng/Nm^3	ng/Nm^3 at 12% CO_2	µg/Mg feed	
Mass burn								
Waterwall								
ESP								
Chicago[a]	Normal				160	214	819	
Hampton (1981)[b]	Normal				5,990	10,900	41,200	
Hampton (1982)[c]	Normal				385	382	1,770	
Hampton (1983)[b]	Normal				8,210	7,640	37,300	
Hampton (1984)[b]	Normal				8,260	14,800	37,500	
N. Andover[d,e]	Normal	143	172		256	323		
Peekskill (4/85)[b]	Normal						317	
Saugus[b]	Normal				346	411		
Tulsa (Units 1 and 2)[b]	Normal				12.7	15.5	61	
Umea, fall[b]	Normal					312		
Umea, fall[b]	Low temp					404		
Umea, spring[b]	Normal					224		
WSH/DI/FF								
Quebec[f]	110	197	334		1.47	2.49		99.3
Quebec[f,g]	125	635	1,030		0.0			
Quebec[f]	140	665	1,070		0.645	1.03		99.9
Quebec[f]	200	357	588		0.767	1.26		99.8
Wurzburg[b]	Normal				19.6	27.9	79.2	
SD/FF								
Marion County[b]	Normal					0.423	1.94	
Quebec[f,g]	140	476	689		0.0			
Quebec[f]	140 & R.	568	908		0.592	0.947		99.9
Refractory								
ESP								
Philadelphia (NW1)[b]	Normal				2,600	5,890		
Philadelphia (NW2)[b]	Normal				1,100	2,870		
CYC								
Mayport[c]	MSW/waste oil				21.0	32.8	320	
EGB								
Pittsfield[f]	Experimental	157						
Starved air								
No control device								
Cattaraugus County[b]	Normal	200						
Dyersburg[c]	Normal	72.5	124	525				
Prince Edward Island[b]	Normal	92.3	144	569				
Prince Edward Island[b]	Long	99.4	159	574				
Prince Edward Island[b]	High	79.5	96.6	340				
Prince Edward Island[b]	Low	53.5	98.7	411				
ESP								
Red Wing	Normal				1,140	1,810	76,500	

(continued)

TABLE 7-46. (continued)

Facility name	Test condition	Emissions upstream from control device			Emissions downstream from control device			Control effi-ciency, %
		ng/Nm^3	ng/Nm^3 at 12% CO$_2$	µg/Mg feed	ng/Nm^3	ng/Nm^3 at 12% CO$_2$	µg/Mg feed	
RDF fired								
ESP								
Akron[c]	Normal				458	679	1,680	
Albany[h]	Normal				76.2	96.2	474	
Hamilton-Wentworth[b] [i]	F/None				5,010	7,360		
Hamilton-Wentworth[b] [j]	F/Low back				8,880	8,540		
Hamilton-Wentworth[b]	F/Back				6,880	9,110		
Hamilton-Wentworth[b] [i]	F/Back, low front[f]				9,230	12,600		
Hamilton-Wentworth[b] [i]	H/None				4,170	9,300		
Hamilton-Wentworth[b] [i]	H/Low back				2,640	6,910		
CYC/ESP								
Wright Pat. AFB[b]	Normal				85.6	135	1,010	

[a] Sum of tetra- through octachlorodibenzofuran without penta.

[b] Sum of tetra- through octachlorodibenzofuran.

[c] Tetrachlorodibenzofuran only.

[d] Outlet values which represent the average of test runs 3, 4, and 5 were used to obtain a control efficiency value for simultaneous test runs. Inlet runs 1 and 2 were not analyzed due to sampling difficulties.

[e] An apparent increase in concentration occurred across the control device; however, no reason for this increase was indicated in the test reports.

[f] Presented as polychlorodibenzofuran in test report.

[g] A 0.0 indicates below detection limit (values of detection limit not yet received).

[h] Tetra- through heptachlorodibenzofuran.

[i] Average of two test runs.

[j] One test run only.

Isomer-specific PCDF in SI units

7-47 Summary of 2,3,7,8-Substituted and Total Tetrachlorodibenzofuran Emissions from MWC Facilities

7-48 Summary of 2,3,7,8-Substituted and Total Pentachlorodibenzofuran Emissions from MWC Facilities

7-49 Summary of 2,3,7,8-Substituted and Total Hexachlorodibenzofuran Emissions from MWC Facilities

7-50 Summary of 2,3,7,8-Substituted and Total Heptachlorodibenzofuran Emissions from MWC Facilities

TABLE 7-47. SUMMARY OF 2,3,7,8-SUBSTITUTED AND TOTAL TETRACHLORODIBENZOFURAN EMISSIONS FROM MWC FACILITIES

Facility name	Test condition	Emissions upstream from control device		Emissions downstream from control device	
		2,3,7,8-TCDF, ng/Nm^3 at 12% CO_2	Total TCDF, ng/Nm^3 at 12% CO_2	2,3,7,8-TCDF ng/Nm^3 at 12% CO_2	Total TCDF, ng/Nm^3 at 12% CO_2
Mass burn					
Waterwall					
ESP					
Hampton (1982)	Normal			72.4	382
Hampton (1984)	Normal			448	3,440
N. Andover	Normal	11	43	16.3	62
Saugus	Normal			23.3	182
Tulsa (Units 1 and 2)	Normal			2.91	7.31
Umea, fall	Normal			3	103
Umea, fall	Low temp			3.12	104
Umea, spring	Normal			0.96	22.8
WSH/DI/FF					
Wurzburg	Normal			0.25	9.60
SD/FF					
Marion County	Normal			0.168	0.322
Refractory					
ESP					
Philadelphia (NW1)	Normal			57.3	1,090
Philadelphia (NW2)	Normal			33.7	743
CYC					
Mayport	MSW/waste oil			16.0	32.8
Starved air					
No control device					
Cattaraugus County[a]	Normal	2.7	120		
ESP					
Red Wing	Normal			58.5	345
RDF fired					
ESP					
Albany	Normal			2.69	46.9

[a] Not corrected to 12 percent CO_2.

TABLE 7-48. SUMMARY OF 2,3,7,8-SUBSTITUTED AND TOTAL PENTACHLORODIBENZOFURAN EMISSIONS FROM MWC FACILITIES

		Emissions upstream from control device			Emissions downstream from control device		
Facility name	Test condition	1,2,3,7,8-PeCDF, ng/Nm^3 at 12% CO_2	2,3,4,7,8-PeCDF, ng/Nm^3 at 12% CO_2	PeCDF, ng/Nm^3 at 12% CO_2	1,2,3,7,8-PeCDF, ng/Nm^3 at 12% CO_2	2,3,4,7,8-PeCDF, ng/Nm^3 at 12% CO_2	Total PeCDF, ng/Nm^3 at 12% CO_2
Mass burn							
Waterwall							
ESP							
N. Andover	Normal	2	4	18	3.71	7.63	33.2
Saugus	Normal				5.9	10.4	106
Tulsa (Units 1 and 2)	Normal				0.56	1.14	3.34
Umea, fall	Normal				11	7.3	116
Umea, fall	Low temp				10	8.9	132
Umea, spring	Normal				3	4.7	51.6
WSH/DI/FF							
Wurzburg	Normal				0.84[a]	0.62	9.26
SD/FF							
Marion County	Normal				0.01	0.015	0.044
Refractory							
ESP							
Philadelphia (NW1)	Normal				117	285	1,210
Philadelphia (NW2)	Normal				86	106	1,030
Starved air							
ESP							
Red Wing	Normal				17.8	75.3	447

[a] Includes 1,2,3,4,8-PeCDF.

TABLE 7-49. SUMMARY OF 2,3,7,8-SUBSTITUTED AND TOTAL HEXACHLORODIBENZOFURAN EMISSIONS FROM MWC FACILITIES

		Emissions upstream from control device					Emissions downstream from control device				
Facility name	Test condition	1,2,3,4,7,8-HxCDF, ng/Nm³ at 12% CO_2	1,2,3,6,7,8-HxCDF, ng/Nm³ at 12% CO_2	1,2,3,7,8,9-HxCDF, ng/Nm³ at 12% CO_2	2,3,4,6,7,8-HxCDF, ng/Nm³ at 12% CO_2	Total HxCDF, ng/Nm³ at 12% CO_2	1,2,3,4,7,8-HxCDF, ng/Nm³ at 12% CO_2	1,2,3,6,7,8-HxCDF, ng/Nm³ at 12% CO_2	1,2,3,7,8,9-HxCDF, ng/Nm³ at 12% CO_2	2,3,4,6,7,8-HxCDF, ng/Nm³ at 12% CO_2	Total HxCDF, ng/Nm³ at 12% CO_2
Mass burn											
Waterwall											
ESP											
N. Andover	Normal	4	1	0.0		11	11.3	3.46	0.0		22.4
Saugus	Normal						13.0	7.8	0.0		69.5
Tulsa (Units 1 and 2)	Normal						0.67	0.27	0.11	0.72	1.82
Umea, fall	Normal						4.3[a]	4.4	1.0	3.1	39.6
Umea, fall	Low temp						6.2[a]	6.0	1.4	6.1	60
Umea, spring	Normal						5.4[a]	5.5	4.3	5.2	51.6
WSH/DI/FE											
Wurzburg	Normal						0.42[a]	0.49	0.08	0.62	6.04
SD/FF											
Marion County	Normal						0.004	0.004	0.005	0.005	0.013
Refractory											
ESP											
Philadelphia (NW1)	Normal						293	729			2,810
Philadelphia (NW2)	Normal						112	143			799
Starved air											
ESP											
Red Wing	Normal						129	53.2	<0.0123	111	478

[a] Includes 1,2,3,4,7,9-HxCDF.

TABLE 7-50. SUMMARY OF 2,3,7,8-SUBSTITUTED AND TOTAL HEPTACHLORODIBENZOFURAN EMISSIONS FROM MWC FACILITIES

		Emissions upstream from control device			Emissions downstream from control device		
Facility name	Test condition	1,2,3,4,6,7,8-HpCDF, ng/Nm^3 at 12% CO_2	1,2,3,4,7,8-HpCDF, ng/Nm^3 at 12% CO_2	Total HpCDF, ng/Nm^3 at 12% CO_2	1,2,3,4,6,7,8-HpCDF, ng/Nm^3 at 12% CO_2	1,2,3,4,7,8,9-HpCDF, ng/Nm^3 at 12% CO_2	Total HpCDF, ng/Nm^3 at 12% CO_2
Mass burn							
Waterwall							
ESP							
Tulsa (Units 1 and 2)	Normal				1.79	0.21	2.35
WSH/DI/FF							
Wurzburg	Normal				1.71	0.06	2.08
SD/FF							
Marion County	Normal				0.007	0.010	0.008
Refractory							
ESP							
Philadelphia (NW1)	Normal				559	39	731
Philadelphia (NW2)	Normal				188	18	266
Starved air							
ESP							
Red Wing	Normal				279	20.6	422

Other organic pollutants in SI units

7-51 Summary of Polychlorinated Biphenyls Emissions From MWC Facilities

7-52 Summary of Formaldehyde Emissions From MWC Facilities

7-53 Summary of Benzo-a-pyrene Emissions From MWC Facilities

7-54 Summary of Total Measured Chlorinated Benzene Emissions From MWC Facilities

7-55 Summary of Total Measured Chlorinated Phenol Emissions From MWC Facilities

TABLE 7-51. SUMMARY OF POLYCHLORINATED BIPHENYLS EMISSIONS FROM MWC FACILITIES

Facility name	Test condition	Emissions upstream from control device			Emissions downstream from control device			Control effi-ciency, %
		ng/Nm^3	ng/Nm^3 at 12% CO_2	µg/Mg feed	ng/Nm^3	ng/Nm^3 at 12% CO_2	µg/Mg feed	
Mass burn								
Waterwall								
ESP								
Chicago	Normal				42.0	56.2	212	
Hampton (1981)	Normal				717	1,300	4,960	
Hampton (1983)	Normal				670	623	3,040	
WSH/DI/FF								
Quebec	110	20.7	35.1		5.72	9.66		72.4
Quebec	125	438	711		3.83	6.21		99.1
Quebec[a]	140	20.6	33.0		0.0			
Quebec	200	12	19.8		5.51	9.06		53.7
SD/FF								
Quebec[a]	140	12.9	18.7		0.0			
Quebec[a]	140 & R.	13.9	22.4		0.0			
Starved air								
No control device								
Prince Edward Island	Normal	522	815	3,410				
Prince Edward Island	Long	36.9	59.0	245				
Prince Edward Island	Low	69.3	128	574				
RDF fired								
ESP								
Albany	Normal				215	272	1,340	
Hamilton-Wentworth[b]	F/None				524,000	762,000		
Hamilton-Wentworth[c]	F/Low back				155,000	150,000		
Hamilton-Wentworth	F/Back				601,000	714,000		
Hamilton-Wentworth[b]	F/Back, low front				217,000	293,000		
Hamilton-Wentworth[b]	H/None				297,000	666,000		
Hamilton-Wentworth[b]	H/Low back				403,000	654,000		

[a] A 0.0 indicates below detection limit (values of detection limit not yet received)
[b] Average of two test runs.
[c] One test run only.

TABLE 7-52. SUMMARY OF FORMALDEHYDE EMISSIONS FROM MWC FACILITIES

Facility name	Test condition	Emissions upstream from control device			Emissions downstream from control device			Control effi-ciency, %
		ng/Nm^3	ng/Nm^3 at 12% CO_2	mg/Mg feed	ng/Nm^3	ng/Nm^3 at 12% CO_2	mg/Mg feed	
Mass burn								
Waterwall								
ESP								
Hampton (1982)	Normal				1,720,000	1,710,000	7,900	
Starved air								
No control device								
Dyersburg	Normal	19,000	32,400	137				
RDF fired								
ESP								
Akron	Normal				117,000	173,000	428	
Albany	Normal				128,000	162,000	798	

TABLE 7-53. SUMMARY OF BENZO-a-PYRENE EMISSIONS FROM MWC FACILITIES

		Emissions upstream from control device			Emissions downstream from control device			
Facility name	Test condition	ng/Nm^3	ng/Nm^3 at 12% CO_2	μg/Mg feed	ng/Nm^3	ng/Nm^3 at 12% CO_2	μg/Mg feed	Control efficiency, %
Mass burn								
Waterwall								
ESP								
Hampton (1982)	Normal				9,030	8,960	41,600	
Hampton (1983)	Normal				12,000	11,200	54,400	
RDF fired								
ESP								
Albany	Normal				21,000	26,500	131,000	

TABLE 7-54. SUMMARY OF TOTAL MEASURED CHLORINATED BENZENE EMISSIONS FROM MWC FACILITIES

Facility name	Test condition	Emissions upstream from control device			Emissions downstream from control device			Control effi-ciency, %
		ng/Nm^3	ng/Nm^3 at 12% CO_2	µg/Mg feed	ng/Nm^3	ng/Nm^3 at 12% CO_2	µg/Mg feed	
Mass burn								
Waterwall								
ESP								
Chicago	Normal	2,000	2,640	10,100	1,770	2,370	8,920	10.2
Hampton (1981)	Normal				41,400	75,300	28,400	
Hampton (1982)	Normal				302,000	300,000	1,390,000	
Hampton (1984)	Normal				45,300	81,100	206,000	
WSH/DI/FF								
Quebec	110	8,190	13,800		398	671		95.1
Quebec	125	11,300	18,300		187	303		98.3
Quebec	140	7,810	12,500		147	236		98.1
Quebec	200	4,800	7,880		1,810	2,970		62.4
Wurzburg	Normal				796	1,240	3,700	
SD/FF								
Quebec	140	7,650	11,100		58.3	84.3		99.2
Quebec	140 & R.	9,910	15,900		120	191		98.8
Starved air								
No control device								
Prince Edward Island	Normal	2,810	4,390	18,000				
Prince Edward Island	Long	2,010	3,210	12,800				
Prince Edward Island	High	3,320	4,040	16,100				
Prince Edward Island	Low	2,690	4,960	22,000				
RDF fired								
ESP								
Hamilton-Wentworth[a]	F/None				69,400	101,000		
Hamilton-Wentworth[b]	F/Low back				46,400	44,900		
Hamilton-Wentworth	F/Back				34,800	41,400		
Hamilton-Wentworth[a]	F/Back, low front				33,600	45,300		
Hamilton-Wentworth[a]	H/None				24,100	54,100		
Hamilton-Wentworth[a]	H/Low back				22,700	36,800		
CYC/ESP								
Wright Pat. AFB	Normal				901	1,420	8,780	

[a] Average of two test runs.
[b] One test run only.

TABLE 7-55. SUMMARY OF TOTAL MEASURED CHLORINATED PHENOL EMISSIONS FROM MWC FACILITIES

		Emissions upstream from control device			Emissions downstream from control device			
Facility name	Test condition	ng/Nm^3	ng/Nm^3 at 12% CO_2	µg/Mg feed	ng/Nm^3	ng/Nm^3 at 12% CO_2	µg/Mg feed	Control effi- ciency, %
Mass burn								
Waterwall								
ESP								
Chicago[a]	Normal	2,920	3,850	14,700	3,570	4,780	18,000	
Hampton (1981)	Normal				122,000	222,000	839,000	
Hampton (1984)	Normal				214,000	383,000	971,000	
WSH/DI/FF								
Quebec	110	19,100	32,200		535	904		97.2
Quebec	125	15,300	24,600		169	274		98.9
Quebec	140	18,200	29,100		218	349		98.8
Quebec	200	11,900	19,500		5,290	8,700		55.6
SD/FF								
Quebec	140	16,000	23,100		171	248		98.9
Quebec	140 & R.	6,280	10,000		248	397		96.0
Starved air								
None								
Prince Edward Island	Normal	2,790	4,350	18,400				
Prince Edward Island	Long	2,360	3,770	15,000				
Prince Edward Island	High	2,230	2,710	10,800				
Prince Edward Island	Low	3,570	6,590	29,000				
RDF fired								
ESP								
Hamilton-Wentworth[b]	F/None				81,100	118,000		
Hamilton-Wentworth[c]	F/Low back				35,600	34,500		
Hamilton-Wentworth	F/Back				40,900	48,600		
Hamilton-Wentworth[b]	F/Back, low front				15,600	21,000		
Hamilton-Wentworth[b]	H/None				72,700	163,000		
Hamilton-Wentworth[b]	H/Low back				54,100	87,800		
CYC/ESP								
Wright Pat. AFB	Normal				9,080	14,300	88,400	

[a] An increase in concentration occurred across the control device; however, no apparent reason for this increase was identified in the test report.

[b] Average of two test runs.

[c] One test run only.

Supplementary tables in SI

7-56 Summary of Supplementary Chlorodibenzo-p-dioxin Emissions From MWC Facilities

7-57 Summary of Supplementary Chlorodibenzofuran Emissions From MWC Facilities

7-58 Summary of Supplementary Metals Emissions From MWC Facilities

TABLE 7-56. SUMMARY OF SUPPLEMENTARY CHLORODIBENZO-p-DIOXIN EMISSIONS FROM MWC FACILITIES

Facility name	Test condition	2,3,7,8, ng/Nm^3	Tetra, ng/Nm^3	Penta, ng/Nm^3	Hexa, ng/Nm^3	Hepta, ng/Nm^3	Octa, ng/Nm^3	Total measured, ng/Nm^3
Mass burn								
Waterwall/ESP								
Iserlohn	Normal	0.014	1.03				182	183[a]
Montreal (1982)	Normal		0.001	0.004	0.003	0.003	0.002	0.013[b]
Montreal (1983)	Normal		0.09	0.094	0.135	0.144	0.282	0.745[b]
Quebec (1981)	Normal		4.1	14.6	15.5	12.2	1.7	48.1[b]
Umea (1984)	Normal	0.5	43	53	32	18	12	158[b]
Umea (1985)	Normal	0.1	10	49	55	56	53	223[b]
Zurich/Josephstrasse	Normal	0.17	4.4	12	27	26	54	123[b]
Waterwall/DS/ESP								
Hamburg/Stapelfeld	Normal	0.1	6				11	42[c]
MVA-I Borsigstrasse	Normal	0.2	25				13	151[c]
MVA-II Stellinger M.	Normal	0.7	19				15	114[c]
Waterwall/CYC/DI/ESP/FF								
Malmo	Normal	0.01	0.15	0.15				0.30[d]
Waterwall/SD/FF								
Avg Borsigstrasse	Normal	0.02	10.5				57	142[c]
Refractory/SPRAY/ESP								
Toronto I	Normal		55.8	76.2	376	415	86.9	1,010[b]
Refractory/ESP								
Brasschaat	Normal	3.0	40.0	34.0	53.0	67.0	153	347[b]
Harelbeke	Normal	0.97	20.0	396	185	206	202	1,010[b]
Linkoping	Normal	0.025	0.45					0.45[e]
Stuttgart	Normal	0.4	19.4	34	33.8	22.9	9.8	120[b]
Zaandstad	Normal		57.1	231	440	347	452	1,530[b]
Refractory/								
Beveren	Normal		3.6	6.5	35.0	87.5	125	258[b]
Milan I	Normal	2.0	15.3				804	820[a]
Milan II	Normal		0.2				113	113[a]
Starved air								
None								
Lake Cowichan	Normal		4.2	47.6	100	46.2	1.39	199[b]
CS/ESP								
Schio	Processed		8.9					8.9[e]
Schio	Unprocessed		1.8					1.8[e]
Fluid bed								
FF								
Eskjo	RDF	0.5	11.3			31.5	17.7	60.5[f]

[a] Sum of tetra- and octachlorodibenzo-p-dioxin emissions.
[b] Sum of tetra- through octachlorodibenzo-p-dioxin emissions.
[c] Sum of tri- through octachlorodibenzo-p-dioxin emissions.
[d] Sum of tetra- and pentachlorodibenzo-p-dioxin emissions.
[e] Tetrachlorodibenzo-p-dioxin emissions only.
[f] Sum of tetra-,hepta- and octachlorodibenzo-p-dioxin emissions.

TABLE 7-57. SUMMARY OF SUPPLEMENTARY CHLORODIBENZOFURAN EMISSIONS FROM MWC FACILITIES

Facility name	Test condition	2,3,7,8, ng/Nm^3	Tetra, ng/Nm^3	Penta, ng/Nm^3	Hexa, ng/Nm^3	Hepta, ng/Nm^3	Octa, ng/Nm^3	Total measured, ng/Nm^3
Mass burn								
Waterwall/ESP								
Iserlohn	Normal	0.21	19.2				41.3	60.5[a]
Montreal (1982)	Normal		0.002	0.007	0.005	0.004	0.002	0.020[b]
Montreal (1983)	Normal		0.179	0.154	0.095	0.063	0.051	0.542[b]
Quebec (1981)	Normal		45.9	35.6	39	8.4	0.64	130[b]
Umea (1984)	Normal	2.5	86	97	33	34	10	260[b]
Umea (1985)	Normal	0.85	19	43	43	49	33	187[b]
Zurich/Josephstrasse	Normal		24	30	20	14	9	97[b]
Waterwall/DS/ESP								
Hamburg/Stapelfeld	Normal	1.2	37				2	109[c]
MVA-I Borsigstrasse	Normal	3.0	65				3	160[c]
MVA-II Stellinger M.	Normal	4.0	127				2	325[c]
Waterwall/CYC/DI/ESP/FF								
Malmo	Normal	0.5	2	3	26			31[d]
Waterwall/SD/FF								
Avg Borsigstrasse	Normal	5.5	74				25.5	183[c]
Refractory/SPRAY/ESP								
Toronto I	Normal		220	168	344	227	59.2	1,020[b]
Refractory/ESP								
Brasschaat	Normal		196	188	220	372	433	1,410[b]
Harelbeke	Normal		116	209	35.0	337	204	901[b]
Linkoping	Normal	0.6	4.25	5.0	169			178[d]
Stuttgart	Normal	3.8	125	122	13.3	20.3	5.4	286[b]
Zaandstad	Normal		161	272	528	293	67.6	1,320[b]
Refractory/								
Beveren	Normal		16.0	33.0	318	47.5	40.0	455[b]
Milan I	Normal						584	584[e]
Milan II	Normal						90.9	90.9[e]
Starved air								
None								
Lake Cowichan	Normal		35.6	73.1	253	41.6	1.07	404[b]
CS/ESP								
Schio	Processed		23.7					23.7[f]
Schio	Unprocessed		6.6					6.6[f]
Fluid bed								
FF								
Eskjo	RDF		327	53.3	59.7	27.7	12.2	480[b]

[a] Sum of tetra- and octachlorofuran emissions.

[b] Sum of tetra- through octachlorofuran emissions.

[c] Sum of tri- through octachlorofuran emissions.

[d] Sum of tetra-,penta-, and hexachlorofuran emissions.

[e] Octachlorofuran emissions only.

[f] Tetrachlorofuran emissions only.

TABLE 7-58. SUMMARY OF SUPPLEMENTARY METALS EMISSIONS FROM MWC FACILITIES

Facility name	Test condition	Arsenic, ng/Nm^3	Beryllium, ng/Nm^3	Cadmium, ng/Nm^3	Total chromium, ng/Nm^3	Lead, ng/Nm^3	Mercury ng/Nm^3	Nickel, ng/Nm^3
Mass burn								
Waterwall/ESP								
Avesto, Sweden	Pilot, inlet			0.038		0.9	0.225	
Avesto, Sweden	Pilot, outlet			0.024		0.68	0.028	
MVA Lausanne, Switzerland[a]	Normal, outlet			0.04		0.9	0.12	
MVA Munich	Normal, inlet			1.29		21.1	0.08-0.45	
MVA Munich	Normal, outlet			0.02		0.24	0.05-0.2	
Waterwall/								
Issy-les-Moulineaux	Normal, outlet			0.07			0.013	
Saint-ouen	Normal, outlet			1.11		43.2	0.52	

[a] Datum was reported in mg/Nm^3 at 11 percent O_2.

Facility type/structural and airflow design data in English units

7-59a Mass-Burn Facility Structural Design Data
7-59b Mass-Burn Facility Airflow Design Data
7-60 Mass-Burn Operating Data for MWC Facilities
7-61a Starved-Air Facility Structural Design Data
7-51b Starved-Air Facility Airflow Design Data
7-62 Starved-Air Operating Data for MWC Facilities
7-63a RDF-Fired Facility Structural Design Data
7-63b RDF-Fired Facility Airflow Design Data
7-64 RDF-Fired Operating Data for MWC Facilities

TABLE 7-59a. MASS-BURN FACILITY STRUCTURAL DESIGN DATA

	Chamber configuration									
	Primary chamber		Secondary chamber		Heat transfer area		Grate data			
Facility	Geometric configuration	Volume, ft^3	Geometric configuration	Volume, ft^3	Convective, ft^2	Total, ft^2	Manufacturer	No. of sections	Pressure drop, in w.c.	Capacity ton/d
Baltimore							a			750
Braintree					880		b			120
Chicago					19,800		c			400
Gallatin							e			100
Hampton							d	3		125
Kure							e			
Peekskill							a			750
N. Andover	Rectangular	29,000			50,700	53,400				750
Quebec							a			250
Tulsa							c			375
Munich										820[f]
Wurzburg							c			
Tsushima							c			165
Malmo							c			240
Saugus								3		750
Marion Co.										275
Philadelphia NW										375

[a] Von Roll.
[b] Riley Stoker.
[c] Martin.
[d] Detroit Stoker.
[e] O'Connor water-cooled rotary combustor.
[f] 530 ton/d of MSW and 290 ton/d of clarified sludge.

TABLE 7-59b. MASS-BURN FACILITY AIRFLOW DESIGN DATA

	Underfire air							Overfire air				
				Flow distribution, percent						Nozzle data		
Facility	No. of plenums	No. of controlled flows	Flow rate, acfm	Feed	Dry	Combustion	Burnout	Location	Flow direction	Number	Type	Velocity, ft/s

TABLE 7-60. MASS BURN OPERATING DATA FOR MUNICIPAL WASTE COMBUSTOR FACILITIES

Facility name	Feed rate, % design	Temperatures			Flow rate, dscfm	Stack gas concentrations				
		Furnace, °F	Boiler outlet, °F	Stack, °F		O_2, %	CO_2, %	H_2O, %	CO, ppm	THC, ppm
Mass burn										
Waterwall										
ESP										
Baltimore, 5/85	85		610	443	110,000	11.5	7.50	12.1		
Braintree				388	20,900	16.1	4.20	6.3	474	11.3
Chicago		1160		460	52,300	11.4	8.97		163	
Hampton (1981)	98			527	18,800	13.5	6.60			
Hampton (1982)				518	12,800	7.70	12.1			
Hampton (1983)		1480		520	12,700	6.40	12.9		1,130	55.7
Hampton (1984)	86	1500		500	10,100	11.9	6.70		136	
North Andover				585	86,900	10.4	9.4	13.4	32.1	
Peekskill (4/85)	95-112						7.90			
Saugus					91,800	10.5	10.1		30.6	
Tulsa (Unit 1)					40,200		9.80			
Tulsa (Unit 2)					45,300		9.40			
Umea, fall, normal		1480								
Umea, fall, low temp		1000								
Umea, spring		1440								
CYC/FF										
Gallatin				344	13,100	9.40	10.5			348
ESP/WS										
Kure				430	17,200	14.6	6.9			
SD/ESP										
Munich				319	76,100	12.5	7.20	17.4		
CYC/DI/ESP/FF										
Malmo		1500	554		34,000	7.50	11.3			
WSH/DI/FF										
Quebec, 110					2,490	12.7	7.10			
Quebec, 125					2,560	12.4	7.40			
Quebec, 140					2,450	12.5	7.50			
Quebec, 200					2,120	12.9	7.30			
Wurzburg		1660		365	30,600	10.7	7.6	15.5	41	
SD/FF										
Marion County		1580		259	36,600	11.7	8.15		18.5	3
Quebec, 140					2,480	11.8	8.30			
Quebec, 140 & R					2,410	12.5	7.50			
Refractory										
ESP										
Philadelphia (NW1)		1810			77,200	13.9	5.55	24.9	227	4
Philadelphia (NW2)		1730			84,000	14.8	4.7	22.6	182	4
CYC										
Mayport	50			433	8,380	12.8	7.70		31.0	
SD/FF										
Tsushima				400	17,800	14.2	6.20	26.8		
EGB										
Pittsfield						10.7				

TABLE 7-61a. STARVED-AIR FACILITY STRUCTURAL DESIGN DATA

Facility	Chamber configuration				Heat transfer area, ft^2	Grate data	
	Primary chamber		Secondary chamber				
	Geometric configuration	Volume, ft^3	Geometric configuration	Volume, ft^3		Manufacturer	Capacity, ton/d
Barron County							50
Cattaraugus Co.							40
Dyersburg							100
N. Little Rock							25
Prince Edward Island							36
Red Wing							36
Tuscaloosa							90

TABLE 7-61b. STARVED-AIR FACILITY AIRFLOW DESIGN DATA

	Primary air							Secondary air				
				Flow distribution, percent						Nozzle data		
Facility	No. of plenums	No. of controlled flows	Flow rate, acfm	Feed	Dry	Combustion	Burnout	Location	Flow direction	Number	Type	Velocity, ft/s

TABLE 7-62. STARVED AIR OPERATING DATA FOR MUNICIPAL WASTE COMBUSTOR FACILITIES

		Temperatures					Stack gas concentrations				
Facility name	Feed rate, % design	Primary chamber, °F	Secondary chamber, °F	Boiler outlet, °F	Stack, °F	Flow rate, dscfm	O_2, %	CO_2, %	H_2O, %	CO, ppm	THC, ppm
Starved Air											
None											
Cattaraugus County	94										
Dyersburg					490	8,160	12.8	7.03			
N. Little Rock		1460	1720	578	392						
Prince Edward Island, normal		1280	1660		363	5,960	12.2	8.00		43.0	0.5
Prince Edward Island, long		1270	1630		362	5,710	12.5	8.00		25.0	0.5
Prince Edward Island, high		1300	1970		361	4,640	9.10	11.1		27.0	0.7
Prince Edward Island, low		1250	1440		383	6,860	13.5	7.00		28.0	0.7
ESP											
Tuscaloosa	90					44,900	11.3	7.00			

TABLE 7-63a. REFUSE DERIVED FUEL-FIRED FACILITY STRUCTURAL DESIGN DATA

	Chamber configuration						Grate data					
	Primary chamber		Secondary chamber		Heat transfer area							
Facility	Geometric configuration	Volume, ft^3	Geometric configuration	Volume, ft^3	Convective, ft^2	Total, ft^2	Manufacturer	No. of sections	Pressure drop, in. w.c.	Capacity, ton/d	Fuel grade	Fuel charging mechanism
Akron										1,000		
Albany										300		
Hamilton-Wentworth										300		
Malmo										240		
Wright Pat. AFB[a]												
Niagara										1,200		

[a] Originally designed to burn coal, retrofitted to burn RDF.

TABLE 7-63b. REFUSE DERIVED FUEL-FIRED FACILITY AIRFLOW DESIGN DATA

	Underfire air							Overfire secondary air				
				Flow distribution, percent						Nozzle data		
Facility	No. of plenums	No. of controlled flows	Flow rate, acfm	Feed	Dry	Combustion	Burnout	Location	Flow direction	Number	Type	Velocity, ft/s

TABLE 7-64. RDF-FIRED OPERATING DATA FOR MUNICIPAL WASTE COMBUSTOR FACILITIES

Facility name	Feed rate, % design	Temperatures			Flow rate, dscfm	Stack gas concentrations				
		Furnace, °F	Boiler outlet, °F	Stack, °F		O_2, %	CO_2, %	H_2O, %	CO, ppm	THC, ppm
RDF fired										
ESP										
Akron				451	48,900	12.7	8.10			
Albany				393	77,400	11.3	9.50	13.4	274	
Niagara	75-90				143,000					
CYC/ESP										
Wright Pat. AFB					48,800		7.60			
Wright Pat. AFB			302	303						
CYC/DI/ESP/FF										
Malmo		1500	541		33,300	7.60	11.5			

Control device design and operating characteristics in English units

7-65 Electrostatic Precipitator Design Specifications

7-66 Electrostatic Precipitator Operating Conditions

7-67 Dry Scrubber/Fabric Filter System Design Specifications

7-68 Dry Scrubber/Fabric Filter System Operating Conditions

7-69 Fabric Filter or Scrubber Design Specifications

7-70 Fabric Filter or Scrubber Operating Conditions

TABLE 7-65. ELECTROSTATIC PRECIPITATOR DESIGN SPECIFICATIONS

Facility name	Particulate matter		Specific collec-tion area, $ft^2/acfm$	No. of fields	Collection plate area, ft^2	Electrical power, kVA	Aspect ratio, length/height	Inlet gas flow rate, acfm	Inlet gas temp., °F	Gas velo-city, ft/s
	Collection efficiency, %	Emissions, gr/dscf								
Mass burn										
Waterwall										
ESP										
Baltimore				4	100,000			173,900	415	
Braintree	93.0		0.131	1	4,740			36,000		3.41
Chicago	97.0	0.05						135,000	500	3.00
Hampton (1981)				2						
Hampton (1983)				2						
Hampton (1984)				2						
North Andover		0.05		3						
Peekskill (4/85)		0.03		3						
Saugus				2						
SD/ESP										
Munich				2					300	
CYC/DI/ESP/FF										
Malmo								46,000	428	
Refractory										
ESP										
Philadelphia (NW1)	98.1		0.206	2	47,400			230,000	550	3.79
Philadelphia (NW2)	98.1		0.206	2	47,400			230,000	550	3.79
CYC/ESP										
Washington, D.C.	95.0			2						
Starved air										
ESP										
Tuscaloosa	50.0	0.03	0.140	2	10,600	27.0	0.52	76,000	350	4.18
RDF fired										
ESP										
Albany				3						
CYC/DI/ESP/FF										
Malmo								46,000	428	

TABLE 7-66. ELECTROSTATIC PRECIPITATOR OPERATING CONDITIONS

Facility name	Test condition	Particulate matter: Collection efficiency, %	Particulate matter: Emissions at 12% CO_2 gr/dscf	Stack opacity, %	Gas temp., °F	Gas flow rate, acfm	Secondary voltage, kVDC: First field	Secondary voltage, kVDC: Second field	Secondary voltage, kVDC: Third field	Secondary current, mADC: First field	Secondary current, mADC: Second field	Secondary current, mADC: Third field
Mass burn												
Waterwall												
ESP												
Baltimore	Normal	99.9	0.003									
Braintree	Normal	75.7	0.239									
Chicago	Normal				388[a]	36,000[a]						
Hampton (1981)	Normal				457[b]	100,000[b]						
Hampton (1983)	Normal				527[a]	41,000[a]						
Hampton (1984)	Normal		0.150		520[b]	28,200[b]	22.0	22.0		68.0	216	
Peekskill (4/85)	Normal		0.016		496[a]	21,000[a]						
ESP/WS												
Kure	Normal	98.4	0.30		531[b]	40,000[b]						
CYC/DI/ESP/FF												
Malmo	Normal	99.5	0.010									
Refractory												
ESP												
Philadelphia (MW1)	Normal		0.110		513[a]	190,000[a]				430	300	
Philadelphia (MW2)	Normal		0.480		513[a]	200,000[a]				275	575	
Starved air												
ESP												
Tuscaloosa	Normal			3	613[b]	84,800[b]	24.0	20.0		43.0	92.0	
RDF fired												
ESP												
Albany	Normal	97.0	0.139		393[a]	144,000[a]	31.0	28.0	28.0	150	280	280
CYC/ESP												
Wright Pat. AFB	Normal				457[a]	91,100[a]						
Wright Pat. AFB	Dense RDF		0.005		282[a]							
CYC/DI/ESP/FF												
Malmo	RDF	99.5										

[a] Control device outlet.
[b] Control device inlet.

TABLE 7-67. DRY SCRUBBER/FABRIC FILTER SYSTEM DESIGN SPECIFICATIONS

Facility name	Particulate matter Collection efficiency, %	 Emissions, gr/dscf	Inlet gas flow rate, acfm	Reagent	Reagent feed method	Gas temperature Inlet, °F	 Outlet, °F	Bag material	A/C ratio, ft/min	Bag cleaning method
Mass burn										
Waterwall										
CYC/DI/ESP/FF										
Malmo		0.02	46,000	$Ca(OH)_2$	Nozzles	428				
WSH/DI/FF										
Quebec[a]				$Ca(OH)_2$	Dry and wet			Teflon	1.3	Pulse-jet
Wurzburg					Dry					Pulse-jet
SD/FF										
Marion County			61,440[b]			440-515	258		2.34	Reverse air
Refractory										
SD/FF										
Tsushima				$Ca(OH)_2$	Two fluid nozzles	680		Fiberglass		Reverse air
RDF fired										
CYC/DI/ESP/FF										
Malmo		0.02	46,000	$Ca(OH)_2$	Nozzles	428				

[a] These data also apply to the SD/FF pilot-scale tests.

[b] At 440°F.

TABLE 7-68. DRY SCRUBBER/FABRIC FILTER SYSTEM OPERATING CONDITIONS

		Particulate matter			Gas temperature				Pressure drop	
Facility name	Test condition	Collection efficiency, %	Emissions 12% CO_2, gr/dscf	Gas flow rate, acfm	Inlet, °F	Outlet, °F	Stoichio-metric ratio	Reagent feed rate, lb/h	Scrubber, in. w.c.	Bags, in. w.c.
Mass burn										
Waterwall										
CYC/DI/ESP/FF										
Malmo	Normal	99.5	0.010							
WSH/DI/FF										
Quebec[a]	Pilot DS	99.9		440[b]	505	311		7.89		
Wurzburg	Normal			49,700[c]	428	365				
Refractory										
SD/FF										
Tsushima	Normal	99.4	0.012	39,200[b]	670	400		44.0	2.70	6.40
RDF fired										
CYC/DI/ESP/FF										
Malmo	RDF	99.5								

[a] These data also apply to the SD/FF pilot-scale tests.

[b] Control device inlet.

[c] Control device outlet.

TABLE 7-69. FABRIC FILTER OR SCRUBBER DESIGN SPECIFICATIONS

Facility name	Particulate matter		Inlet gas flow rate, acfm	Inlet gas temp., °F	Fabric filter			Scrubber		
	Collection efficiency, %	Emissions, gr/dscf			A/C ratio, ft/min	Bag cleaning method	Bag material	Type	Pressure drop, in. w.c.	Liquid rate, gal/min
Mass burn										
Waterwall										
ESP/WS										
Kure								TCA		
SD/ESP										
Munich				500						
Refractory										
WS										
Alexandria								Imp.		
Nicosia								Imp.		1,050

TABLE 7-70. FABRIC FILTER OR SCRUBBER OPERATING CONDITIONS

Facility name	Test condition	Particulate matter		Inlet gas flow rate, acfm	Gas temperature		Pressure drop, in. w.c.	Bag cleaning cycle, min	Stoichio-metric ratio
		Collection efficiency, %	Emissions at 12% CO_2, gr/dscf		Inlet, °F	Outlet, °F			
Mass burn									
Waterwall									
CYC/FF									
Gallatin	Normal	98.9	0.032	18,300	446	341			
ESP/WS									
Kure	Normal	98.4	0.030						
SD/ESP									
Munich	MSW only			152,000	510	318			6.5[a]
CYC/DI/ESP/FF									
Malmo	Normal	99.5	0.010						
WSH/DI/FF									
Quebec	Pilot DS	99.9							
Refractory									
SD/FF									
Tsushima	Normal	99.4	0.012						
RDF fired									
CYC/DI/ESP/FF									
Malmo	RDF	99.5							

[a] Reagent versus HCl and SO_2.

Criteria pollutants in English units

7-71 Summary of Particulate Emissions From MWC Facilities

7-72 Summary of Carbon Monoxide Emissions From MWC Facilities

7-73 Summary of Sulfur Dioxide Emissions From MWC Facilities

7-74 Summary of Oxides of Nitrogen Emissions From MWC Facilities

TABLE 7-71. SUMMARY OF PARTICULATE EMISSIONS FROM MWC FACILITIES

Facility name	Test condition	Emissions upstream from control device		Emissions downstream from control device		Control efficiency, %
		gr/dscf at 12% CO_2	lb/ton feed	gr/dscf at 12% CO_2	lb/ton feed	
Mass burn						
Waterwall						
ESP						
Baltimore, 1/85	Normal			0.002	0.05	
Baltimore, 5/85	Normal	2.05	46.5	0.003	0.059	99.9
Braintree	Normal	0.979	13.0	0.239	3.02	75.6
Hampton (1981)	Normal			0.401	6.95	
Hampton (1982)	Normal			0.185	3.92	
Hampton (1984)	Normal			0.071		
McKay Bay (Unit 1)[a] [b]	Normal	1.96		0.013		
McKay Bay (Unit 2)[b]	Normal	2.18		0.012		
McKay Bay (Unit 3)[b]	Normal	1.61		0.003		
McKay Bay (Unit 4)[b]	Normal	1.68		0.008		
N. Andover	Normal	0.935		0.005		99.5
Peekskill (4/85)	Normal			0.043		
Tulsa (Unit 1)	Normal			0.009	0.177	
Tulsa (Unit 2)	Normal			0.005	0.094	
CYC/FF						
Gallatin	Normal	2.92	42.5	0.032	0.685	98.9
ESP/WS						
Kure	Normal	1.88	36.4	0.030	0.408	98.4
SD/ESP						
Munich	MSW only	2.89	49.9	0.010	0.185	99.6
CYC/DI/ESP/FF						
Malmo	Normal	1.95	50.8	0.010	0.264	99.5
WSH/DI/FF						
Quebec	110	3.70				
Quebec	125	3.46				
Quebec	140	2.91				
Quebec	200	2.61				
Wurzburg	Normal			0.004	0.055	
SD/FF						
Marion County	Normal			0.007	0.154	
Quebec	140	2.53				
Quebec	140 & R.	3.35				
Refractory						
ESP						
Philadelphia (NW1)	Normal			0.110		
Philadelphia (NW2)	Normal			0.580		
CYC						
Mayport	MSW/waste oil			0.669	13.0	
SD/FF						
Tsushima	Normal	1.95	24.7	0.012	0.151	99.4
Starved air						
No control device						
Dyersburg	Normal	0.132	2.60			
N. Little Rock, 3/78[c]	Normal	0.143				
N. Little Rock, 5/78[c]	Normal	0.191				
N. Little Rock, 10/78[c]	Normal	0.13	3.03			
Prince Edward Island	Normal	0.093	1.68			
Prince Edward Island	Long	0.103	1.74			
Prince Edward Island	High	0.111	2.0			
Prince Edward Island	Low	0.075	1.36			
ESP						
Barron County	Normal			0.01	0.196	
Red Wing	Normal			0.049	0.939	
Tuscaloosa[d]	Normal	0.086	1.45	0.062	1.04	27.9
RDF fired						
ESP						
Akron	Normal			0.233	2.63	
Albany	Normal	4.65	103	0.139	3.09	97.0
Hamilton-Wentworth[a]	F/None			0.312		
Hamilton-Wentworth[e]	F/Low back			0.0387		
Hamilton-Wentworth	F/Back			0.226		
Hamilton-Wentworth[a]	F/Back, low front			0.0926		
Hamilton-Wentworth[a]	H/None			0.101		
Hamilton-Wentworth[a]	H/Low back			0.0533		
Niagara	Normal			0.096		

(continued)

TABLE 7-71. (continued)

		Emissions upstream from control device		Emissions downstream from control device		
Facility name	Test condition	gr/dscf at 12% CO_2	lb/ton feed	gr/dscf at 12% CO_2	lb/ton feed	Control efficiency, %
CYC/DI/ESP/FF Malmo	RDF	1.89	58.2			

[a] Average of two test runs.
[b] Control efficiency not calculated because inlet and outlet test runs were not simultaneous.
[c] Not corrected to dry standard conditions.
[d] Control efficiency is not typical of most properly maintained ESP's.
[e] One test run only.

TABLE 7-72. SUMMARY OF CARBON MONOXIDE EMISSIONS FROM MWC FACILITIES

Facility name	Test condition	Emissions upstream from control device		Emissions downstream from control device		Control effi-ciency, %
		ppmdv at 12% CO_2	lb/ton feed	ppmdv at 12% CO_2	lb/ton feed	
Mass burn						
Waterwall						
ESP						
Baltimore, 1/85	Normal			19.6	0.212	
Braintree	Normal			1,350	8.72	
Chicago	Normal	189	1.68	197	1.70	
Hampton (1983)	Normal			1,050		
Hampton (1984)	Normal			242		
McKay Bay (unit 1)[a]	Normal			30		
McKay Bay (unit 2)[a]	Normal			35		
McKay Bay (unit 3)[a]	Normal			31.7		
McKay Bay (unit 4)[a]	Normal			31.7		
N. Andover	Normal			42.4		
Saugus	Normal			36.3		
Tulsa (Unit 1)	Normal			20.1	0.098	
Tulsa (Unit 2)	Normal			23.8	0.119	
CYC/FF						
Gallatin	Normal			516	4.50	
ESP/WS						
Kure	Normal	630	5.08			
CYC/DI/ESP/FF						
Malmo	Normal			158	2.10	
WSH/DI/FF						
Quebec	110			151		
Quebec	125			189		
Quebec	140			211		
Quebec	200			166		
Wurzburg	Normal			41	0.254	
SD/FF						
Marion County	Normal			18.5	0.196	
Quebec	140			133		
Quebec	140 & R.			174		
Refractory						
ESP						
Philadelphia (NW1)	Normal			515		
Philadelphia (NW2)	Normal			464		
CYC						
Mayport	MSW/waste oil	48.3	0.551			
Starved air						
No control device						
N. Little Rock, 10/78[b]	Normal	84.9	1.0			
Prince Edward Island	Normal	67.0	0.636			
Prince Edward Island	Long	40.0	0.354			
Prince Edward Island	High	33.0	0.292			
Prince Edward Island	Low	52.0	0.505			
ESP						
Barron County	Normal			3.24	0.0317	
Red Wing	Normal			<2.11	<0.0211	
RDF fired						
ESP						
Albany	Normal			346	3.93	
Hamilton-Wentworth[c]	F/None			636		
Hamilton-Wentworth[d]	F/Low back			501		
Hamilton-Wentworth[c]	F/Back			430		
Hamilton-Wentworth[c]	F/Back, low front			411		
Hamilton-Wentworth[c]	H/None			2,090		
Hamilton-Wentworth[c]	H/Low back			1,210		
CYC/DI/ESP/FF						
Malmo	RDF			217	3.41	

[a] Not corrected to 12 percent CO_2.

[b] Not corrected to dry standard conditions.

[c] Average of two test runs.

[d] One test run only.

TABLE 7-73. SUMMARY OF SULFUR DIOXIDE EMISSIONS FROM MWC FACILITIES

		Emissions upstream from control device		Emissions downstream from control device		
Facility name	Test condition	ppmdv at 12% CO_2	lb/ton feed	ppmdv at 12% CO_2	lb/ton feed	Control efficiency, %
Mass burn						
Waterwall						
ESP						
Baltimore, 1/85	Normal			114	2.74	
Braintree	Normal			136	2.01	
McKay Bay (Unit 1)	Normal			98.6		
McKay Bay (Unit 3)	Normal			111		
McKay Bay (Unit 4)[a]	Normal			177		
Tulsa (Unit 1)	Normal			94.9	1.99	
Tulsa (Unit 2)	Normal			80.9	1.83	
CYC/FF						
Gallatin	Normal	141	2.38	141	3.50	
ESP/WS						
Kure	Normal	89.6	2.02	13.5	0.195	87.1
SD/ESP						
Munich[b]	MSW only	92.0	2.31	21.7	0.562	76.4
WSH/DI/FF						
Quebec	110	128		4.86		96.2
Quebec	125	127		10.8		91.5
Quebec	140	129		28.2		78.1
Quebec	200	118		90.3		23.5
Wurzburg	Normal			209	3.27	
SD/FF						
Marion County	Normal			41.5	1.03	
Quebec	140	108		35.8		67.0
Quebec	140 & R.	111		44.8		59.6
Refractory						
ESP						
Philadelphia (NW1)	Normal			401		
Philadelphia (NW2)	Normal			375		
SD/FF						
Tsushima	Normal	12.7	0.180	0.040	0.0009	99.7
Starved air						
No control device						
N. Little Rock, 10/78[c]	Normal	<29.3	<0.78			
Prince Edward Island	Normal	61.0	1.32			
Prince Edward Island	Long	83.0	1.68			
Prince Edward Island	High	75.0	1.52			
Prince Edward Island	Low	87.0	1.93			
ESP						
Red Wing	Normal			124	2.84	
RDF fired						
ESP						
Albany	Normal			188	5.0	
Hamilton-Wentworth[a]	F/None			58.9		
Hamilton-Wentworth	F/Back			54.7		
Hamilton-Wentworth[a]	F/Back, low front			57.3		
Hamilton-Wentworth[a]	H/None			49.3		
Hamilton-Wentworth[a]	H/Low back			67.3		
Niagara	Normal				2.82	

[a] Average of two test runs.

[b] This data represents a combined SO_2 and SO_3 value because separate values were not reported.

[c] Not corrected to dry standard conditions.

TABLE 7-74. SUMMARY OF OXIDES OF NITROGEN EMISSIONS FROM MWC FACILITIES

Facility name	Test condition	Emissions upstream from control device		Emissions downstream from control device		Control effi-ciency, %
		ppmdv at 12% CO_2	lb/ton feed	ppmdv at 12% CO_2	lb/ton feed	
Mass burn						
Waterwall						
ESP						
Baltimore, 1/85	Normal			196	3.38	
Braintree	Normal			153	1.62	
McKay Bay (Unit 1)	Normal			103		
McKay Bay (Unit 2)	Normal			39		
McKay Bay (Unit 3)	Normal			100		
McKay Bay (Unit 4)	Normal			106		
Tulsa (Unit 1)	Normal			358	5.71	
Tulsa (Unit 2)	Normal			376	6.15	
CYC/FF						
Gallatin	Normal	140	2.20			
ESP/WS						
Kure	Normal	159	2.50			
WSH/DI/FF						
Wurzburg	Normal			294	3.18	
SD/FF						
Marion County	Normal			294	5.26	
Refractory						
ESP						
Philadelphia (NW1)	Normal			195		
Philadelphia (NW2)	Normal			215		
SD/FF						
Tsushima	Normal			168	1.79	
Starved air						
No control device						
N. Little Rock, 10/78[a]	Normal	240	3.68			
Prince Edward Island	Normal	309	4.82			
Prince Edward Island	Long	271	3.94			
Prince Edward Island	High	258	3.75			
Prince Edward Island	Low	292	4.66			
ESP						
Red Wing	Normal			255	4.19	
Tuscaloosa	Normal			278	3.85	
RDF fired						
ESP						
Albany	Normal			263	4.91	
Niagara	Normal				3.91	

[a] Not corrected to dry standard conditions.

Metals in English units

7-75 Summary of Arsenic Emissions From MWC Facilities

7-76 Summary of Beryllium Emissions From MWC Facilities

7-77 Summary of Cadmium Emissions From MWC Facilities

7-78 Summary of Total Chromium Emissions From MWC Facilities

7-79 Summary of Lead Emissions From MWC Facilities

7-80 Summary of Mercury Emissions From MWC Facilities

7-81 Summary of Nickel Emissions From MWC Facilities

TABLE 7-75. SUMMARY OF ARSENIC EMISSIONS FROM MWC FACILITIES

Facility name	Test condition	Emissions upstream from control device			Emissions downstream from control device			Control efficiency, %
		$\times 10^{-6}$ gr/dscf at 12% CO_2	$\times 10^{-6}$ lb/lb Particulate	$\times 10^{-6}$ lb/ton feed	$\times 10^{-6}$ gr/dscf at 12% CO_2	$\times 10^{-6}$ lb/lb Particulate	$\times 10^{-6}$ lb/ton feed	
Mass burn								
Waterwall								
ESP								
Baltimore, 5/85[a]	Normal	105	51.2	2,780	2.75	1,020	60.8	97.4
Braintree	Normal	62.5	63.8	830	20.0	83.9	253	68.0
Hampton (1982)	Normal				102	549	2,160	
N. Andover	Normal	408	436		4.54	929		98.9
CYC/FF								
Gallatin	Normal	213	72.9	3,180				
ESP/WS								
Kure	Normal	126	67.0	15,000				
SD/ESP								
Munich	MSW only				0.198	19.0	3.60	
WSH/DI/FF								
Quebec	110	70.2	19.0		0.009			>99.9
Quebec	125	48.9	14.2		0.019			>99.9
Quebec	140	61.3	21.1		0.018			>99.9
Quebec	200	35.1	13.4		0.032			99.9
Wurzburg[b]	Normal				0.003	0.754	0.041	
SD/FF								
Quebec	140	48.4	19.2		0.018			>99.9
Quebec	140 & R.	59.1	17.7		0.014			>99.9
Refractory								
CYC/ESP								
Washington, D.C.	Normal					310		
WS								
Alexandria						210		
Nicosia	Normal					200		
SD/FF								
Tsushima[b]	Normal	26.9	13.8	400	0.143	11.9	1.60	99.5
Starved air								
No control device								
Dyersburg	Normal	50.6	382	994				
Prince Edward Island	Normal	2.66	28.5	52.0				
Prince Edward Island	Long	4.45	43.6	72.0				
Prince Edward Island	High	7.59	68.2	142				
Prince Edward Island	Low	3.57	47.3	66.0				
ESP								
Barron County	Normal				8.5	850	166	
Red Wing	Normal				12.6	259	247	
Tuscaloosa[a]	Normal	52.0	605	884	19.1	308	328	63.3

(continued)

TABLE 7-75. (continued)

Facility name	Test condition	Emissions upstream from control device: $\times10^{-6}$ gr/dscf at 12% CO_2	Emissions upstream from control device: $\times10^{-6}$ lb/lb Particulate	Emissions upstream from control device: $\times10^{-6}$ lb/ton feed	Emissions downstream from control device: $\times10^{-6}$ gr/dscf at 12% CO_2	Emissions downstream from control device: $\times10^{-6}$ lb/lb Particulate	Emissions downstream from control device: $\times10^{-6}$ lb/ton feed	Control efficiency, %
RDF fired								
ESP								
Akron	Normal				66.4	300	751	
Albany	Normal				8.35	60.1	186	
Niagara	Normal						192	

[a] Specific Arsenic run used to measure reported data.
[b] One test run only.

TABLE 7-76. SUMMARY OF BERYLLIUM EMISSIONS FROM MWC FACILITIES

Facility name	Test condition	Emissions upstream from control device			Emissions downstream from control device			Control efficiency, %
		x10^{-6} gr/dscf at 12% CO_2	x10^{-6} lb/lb Partic-ulate	x10^{-6} lb/ton feed	x10^{-6} gr/dscf at 12% CO_2	x10^{-6} lb/lb Partic-ulate	x10^{-6} lb/ton feed	
Mass burn								
Waterwall								
ESP								
Braintree[a]	Normal	0.036	0.041	0.475	0.037	0.156	0.483	
Hampton (1982)	Normal				0.009	0.047	0.184	
McKay Bay (Unit 1)	Normal				0.0725			
McKay Bay (Unit 2)	Normal				0.0452			
McKay Bay (Unit 3)	Normal				0.111			
McKay Bay (Unit 4)	Normal				0.040			
Tulsa (Units 1 and 2)	Normal				0.001	0.140	0.025	
CYC/FF								
Gallatin	Normal	3.21	1.10	48.0				
SD/ESP								
Munich	MSW only				0.0002	0.021	0.373	
WSH/DI/FF								
Quebec[b]	110	0.0			0.0			
Quebec[b]	125	0.0			0.0			
Quebec[b]	140	0.0			0.0			
Quebec[b]	200	0.0			0.0			
SD/FF								
Marion County	Normal				0.00109		0.0214	
Quebec[b]	140	0.0			0.0			
Quebec[b]	140 & R.	0.0			0.0			
Refractory								
SD/FF								
Tsushima[c]	Normal	20.5	10.5	300	0.143	11.9	1.60	99.3
Starved air								
No control device								
Dyersburg	Normal	0.048	0.363	0.945				
N. Little Rock, 10/78[d]	Normal	0.146	1.12	3.6				
ESP								
Red Wing	Normal				0.0420	0.866	0.826	
RDF fired								
ESP								
Albany	Normal				9.00	64.8	200	
Niagara	Normal						0.962	

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[a] An increase in concentration occurred across the control device; however, the difference between inlet and outlet values is within the imprecision associated with the sampling and analysis techniques.

[b] A 0.0 indicates below detection limit (values of detection limit not yet received).

[c] One test run only.

[d] Not corrected to dry standard conditions.

TABLE 7-77. SUMMARY OF CADMIUM EMISSIONS FROM MWC FACILITIES

		Emissions upstream from control device			Emissions downstream from control device			
Facility name	Test condition	$\times 10^{-6}$ gr/dscf at 12% CO_2	$\times 10^{-6}$ lb/lb Partic-ulate	$\times 10^{-6}$ lb/ton feed	$\times 10^{-6}$ gr/dscf at 12% CO_2	$\times 10^{-6}$ lb/lb Partic-ulate	$\times 10^{-6}$ lb/ton feed	Control efficiency, %
Mass burn								
Waterwall								
ESP								
Braintree	Normal	551	563	7,310	208	870	2,620	62.3
Chicago	Normal				128		2,420	
Hampton (1982)	Normal				219	1,180	4,630	
N. Andover	Normal	195	208		9.75	1,990		95
CYC/FF								
Gallatin	Normal	1,580	541	23,600				
ESP/WS								
Kure	Normal	430	229	51,000				
SD/ESP								
Munich	MSW only				3.75	360	70.0	
CYC/DI/ESP/FF								
Malmo	Normal	301	155	7,860	2.72	268	70.9	99.1
WSH/DI/FF								
Quebec	110	609	165		0.212			>99.9
Quebec$_a$	125	636	184		0.210			>99.9
Quebec^a	140	702	242		0.0			
Quebec	200	458	176		0.278			>99.9
Wurzburg^b	Normal				3.05	750	40.9	
SD/FF								
Quebec^a	140	555	216		0.0			
Quebec^a	140 & R.	533	160		0.0			
Refractory								
CYC/ESP								
Washington, D.C.	Normal					1,900		
WS								
Alexandria	Normal					1,100		
Nicosia	Normal					1,500		
SD/FF								
Tsushima^b	Normal	52.5	26.9	700	4.94	412	110	90.6
Starved air								
No control device								
Dyersburg	Normal	104	784	2,040				
N. Little Rock, 10/78^c	Normal	157	1,210	3,860				
Prince Edward Island	Normal	411	4,400	7,580				
Prince Edward Island	Normal	349	3,420	6,060				
Prince Edward Island	High	355	3,190	6,320				
Prince Edward Island	Low	279	3,690	4,100				
ESP								
Barron County	Normal				9.13	913	166	
Red Wing	Normal				88.7	1,830	1,740	

(continued)

TABLE 7-77. (continued)

		Emissions upstream from control device			Emissions downstream from control device			
Facility name	Test condition	$\times 10^{-6}$ gr/dscf at 12% CO_2	$\times 10^{-6}$ lb/lb Partic-ulate	$\times 10^{-6}$ lb/ton feed	$\times 10^{-6}$ gr/dscf at 12% CO_2	$\times 10^{-6}$ lb/lb Partic-ulate	$\times 10^{-6}$ lb/ton feed	Control efficiency, %
RDF fired								
ESP								
Akron	Normal				163	700	1,850	
Albany	Normal				14.7	106	328	
Niagara	Normal						530	
CYC/DI/ESP/FF								
Malmo	RDF	213	113	6,560				

[a] A 0.0 indicates below detection limit (values of detection limit not yet received).
[b] One test run only.
[c] Not corrected to dry standard conditions.

TABLE 7-78. SUMMARY OF TOTAL CHROMIUM EMISSIONS FROM MWC FACILITIES

		Emissions upstream from control device			Emissions downstream from control device			
Facility name	Test condition	$\times 10^{-6}$ gr/dscf at 12% CO_2[a]	$\times 10^{-6}$ lb/lb Particulate	$\times 10^{-6}$ lb/ton feed	$\times 10^{-6}$ gr/dscf at 12% CO_2	$\times 10^{-6}$ lb/lb Particulate	$\times 10^{-6}$ lb/ton feed	Control efficiency, %
Mass burn								
Waterwall								
ESP								
Baltimore, 5/85[a]	Normal	953	465	21,600	9.31	3,450	202	99.0
Braintree	Normal	274	280	3,640	46.3	194	586	83.1
Hampton (1982)	Normal				124	668	2,620	
N. Andover	Normal	1,870	2,000		335	68,500		82.1
CYC/FF								
Gallatin	Normal	526	180	7,860				
ESP/WS								
Kure	Normal	253	135	30,000				
SD/ESP								
Munich	MSW only				446	43,000	8,040	
WSH/DI/FF								
Quebec	110	1,470	399		0.212			>99.9
Quebec	125	911	263		0.210			>99.9
Quebec	140	938	323		0.465			>99.9
Quebec	200	853	326		0.237			>99.9
Wurzburg[b]	Normal				0.275	67.5	3.68	
SD/FF								
Quebec	140	658	260		0.100			>99.9
Quebec	140 & R.	773	231		0.326			>99.9
Refractory								
CYC/ESP								
Washington, D.C.	Normal					870		
WS								
Alexandria	Normal					490		
Nicosia	Normal					105		
SD/FF								
Tsushima[b]	Normal	1,180	605	16,000	2.34	195	26.0	99.8
Starved air								
No control device								
Dyersburg	Normal	172	1,300	3,380				
N. Little Rock, 10/78[c]	Normal	1.41	10.9	34.6				
Prince Edward Island	Normal	19.0	204	346				
Prince Edward Island	Long	11.6	113	198				
Prince Edward Island	High	51.0	459	890				
Prince Edward Island	Low	11.1	147	204				
ESP								
Barron County	Normal				1.56	156	27.6	
Red Wing	Normal				10.7	221	210	
Tuscaloosa[d]	Normal	16.0	186	272	11.2	181	193	29.8

(continued)

TABLE 7-78. (continued)

Facility name	Test condition	Emissions upstream from control device			Emissions downstream from control device			Control efficiency, %
		$\times 10^{-6}$ gr/dscf at 12% CO_2[a]	$\times 10^{-6}$ lb/lb particulate	$\times 10^{-6}$ lb/ton feed	$\times 10^{-6}$ gr/dscf at 12% CO_2	$\times 10^{-6}$ lb/lb particulate	$\times 10^{-6}$ lb/ton feed	
RDF fired								
ESP								
Akron	Normal				215	925	2,440	
Albany	Normal				2,910	20,900	64,700	
Niagara	Normal						904	

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[a] Inlet hexavalent chromium value of 0.5 μg/g presented in test report.
[b] One test run only.
[c] Not corrected to dry standard conditions.
[d] Control efficiency is not typical of most properly maintained ESP's.

TABLE 7-79. SUMMARY OF LEAD EMISSIONS FROM MWC FACILITIES

Facility name	Test condition	Emissions upstream from control device			Emissions downstream from control device			Control efficiency, %
		$\times 10^{-6}$ gr/dscf at 12% CO_2	$\times 10^{-6}$ lb/lb Particulate	$\times 10^{-6}$ lb/ton feed	$\times 10^{-6}$ gr/dscf at 12% CO_2	$\times 10^{-6}$ lb/lb Particulate	$\times 10^{-6}$ lb/ton feed	
Mass burn								
Waterwall								
ESP								
Braintree	Normal	14,900	15,200	197,000	6,730	28,200	85,100	54.7
Hampton (1982)	Normal				4,150	22,400	88,000	
McKay Bay (Unit 1)	Normal				1,350			
McKay Bay (Unit 2)	Normal				474			
McKay Bay (Unit 3)	Normal				387			
McKay Bay (Unit 4)	Normal				514			
Tulsa (Units 1 and 2)	Normal				181	19,100	3,390	
CYC/FF								
Gallatin	Normal	18,300	6,260	274,000				
ESP/WS								
Kure	Normal	2,110	1,120	250,000				
SD/ESP								
Munich	MSW only				38.5	3,700	700	
CYC/DI/ESP/FF								
Malmo	Normal	6,250	3,210	163,000	57.2	5,650	1,490	99.1
WSH/DI/FF								
Quebec	110	19,600	5,320		1.88			>99.9
Quebec	125	21,200	6,110		1.26			>99.9
Quebec	140	15,800	5,430		2.16			>99.9
Quebec	200	15,800	6,030		2.86			>99.9
Wurzburg[a]	Normal				6.00	1,500	81.8	
SD/FF								
Marion County	Normal				11.0		292	
Quebec	140	16,400	6,490		0.538			>99.9
Quebec	140 & R.	15,800	4,710		2.82			>99.9
Refractory								
CYC/ESP								
Washington, D.C.	Normal					78,000		
WS								
Alexandria	Normal					97,000		
Nicosia	Normal					69,000		
SD/FF								
Tsushima[a]	Normal	1,230	631	17,000	9.10	758	100	99.3
Starved air								
No control device								
Dyersburg	Normal	6,730	50,000	130,000				
N. Little Rock, 10/78[b]	Normal	5,470	42,100	134,000				
Prince Edward Island	Normal	6,280	67,300	110,000				
Prince Edward Island	Long	6,760	66,200	116,000				
Prince Edward Island	High	6,760	60,800	120,000				
Prince Edward Island	Low	3,730	49,500	68,400				
ESP								
Barron County	Normal				103	10,300	1,930	
Red Wing	Normal				1,480	34,300	29,100	

(continued)

TABLE 7-79. (continued)

Facility name	Test condition	Emissions upstream from control device $\times 10^{-6}$ gr/dscf at 12% CO_2	$\times 10^{-6}$ lb/lb Particulate	$\times 10^{-6}$ lb/ton feed	Emissions downstream from control device $\times 10^{-6}$ gr/dscf at 12% CO_2	$\times 10^{-6}$ lb/lb Particulate	$\times 10^{-6}$ lb/ton feed	Control efficiency, %
RDF fired								
ESP								
Akron	Normal				4,200	18,000	47,400	
Albany	Normal				425	3,060	9,460	
Niagara	Normal						12,900	
CYC/DI/ESP/FF								
Malmo	RDF	4,200	2,220	129,000				

[a] One test run only.
[b] Not corrected to dry standard conditions.

TABLE 7-80. SUMMARY OF MERCURY EMISSIONS FROM MWC FACILITIES

Facility name	Test condition	Emissions upstream from control device: x10^{-6} gr/dscf at 12% CO$_2$	Emissions upstream from control device: x10^{-6} lb/lb Partic-ulate	Emissions upstream from control device: x10^{-6} lb/ton feed	Emissions downstream from control device: x10^{-6} gr/dscf at 12% CO$_2$	Emissions downstream from control device: x10^{-6} lb/lb Partic-ulate	Emissions downstream from control device: x10^{-6} lb/ton feed	Control efficiency, %
Mass burn								
Waterwall								
ESP								
Braintree[a]	Normal	12.5	12.8	166	17.5	73.3	221	
Hampton (1982)	Normal				967	5,220	20,500	
McKay Bay (Unit 1)	Normal				283			
McKay Bay (Unit 2)	Normal				377			
McKay Bay (Unit 3)	Normal				407			
McKay Bay (Unit 4)	Normal				474			
Tulsa (Units 1 and 2)	Normal				183	19,300	3,580	
CYC/FF								
Gallatin	Normal	102	34.9	1,710				
ESP/WS								
Kure	Normal	3.80	2.02	450				
CYC/DI/ESP/FF								
Malmo	Normal	136	70.1	3,560	81.7	8,060	2,130	40.1
WSH/DI/FF								
Quebec	110	213	57.1		19.0			91.0
Quebec	125	228	65.7		6.0			97.4
Quebec	140	148	51.0		9.20			93.8
Quebec[a]	200	204	78.4		279			
SD/FF								
Marion County	Normal				122		2,880	
Quebec	140	84.0	33.3		4.55			94.6
Quebec	140 & R.	167	49.8		8.93			94.6
Refractory								
SD/FF								
Tsushima[b]	Normal	116	59.5	12,000	81.2	6,770	900	30.0
Starved air								
No control device								
Dyersburg	Normal	56.9	430	1,120				
Prince Edward Island	Normal	307	3,290	5,300				
Prince Edward Island	Long	235	2,300	3,940				
Prince Edward Island	High	205	1,850	7,200				
Prince Edward Island	Low	235	3,120	4,320				
ESP								
Red Wing[c]	Normal				260	5,370	5,100	
RDF fired								
ESP								
Akron	Normal				80.4	345	909	
Albany	Normal				193	1,390	4,290	
Niagara	Normal						3,160	
CYC/DI/ESP/FF								
Malmo	RDF	74.3	39.3	2,280				

[a] An apparent increase in concentration occurred across the control device; however, no reason for this increase was indicated in the test report.

[b] One test run only.

[c] Measured using $KMnO_4$ impinger method.

TABLE 7-81. SUMMARY OF NICKEL EMISSIONS FROM MWC FACILITIES

Facility name	Test condition	Emissions upstream from control device: $\times 10^{-6}$ gr/dscf at 12% CO_2	Emissions upstream from control device: $\times 10^{-6}$ lb/lb Particulate	Emissions upstream from control device: $\times 10^{-6}$ lb/ton feed	Emissions downstream from control device: $\times 10^{-6}$ gr/dscf at 12% CO_2	Emissions downstream from control device: $\times 10^{-6}$ lb/lb Particulate	Emissions downstream from control device: $\times 10^{-6}$ lb/ton feed	Control efficiency, %
Mass burn								
Waterwall								
ESP								
Hampton (1982)	Normal				99.1	535	2,100	
N. Andover	Normal	229	244		208	42,600		9
CYC/FF								
Gallatin	Normal	222	75.9	332				
ESP/WS								
Kure	Normal	169	89.9	20,000				
SD/ESP								
Munich	MSW only				208	20,000	3,730	
WSH/DI/FF								
Quebec	110	467	127		0.627			99.9
Quebec	125	844	244		0.210			>99.9
Quebec	140	582	201		0.331			99.9
Quebec	200	378	145		0.698			99.8
Wurzburg[a]	Normal				0.121	30.2	1.65	
SD/FF								
Quebec	140	323	128		0.60			99.8
Quebec	140 & R	1,170	351		0.973			99.9
Refractory								
CYC/ESP								
Washington, D.C.	Normal					170		
WS								
Alexandria	Normal					200		
Nicosia	Normal					79.0		
SD/FF								
Tsushima[a]	Normal	999	512	14,000	130	10,800	1,500	87.0
Starved air								
No control device								
Dyersburg	Normal	47.8	361	939				
N. Little Rock, 10/78[b]	Normal	2.52	19.4	62				
Prince Edward Island	Normal	106	1,130	1,920				
Prince Edward Island	Long	114	1,120	2,000				
Prince Edward Island	High	241	2,170	4,340				
Prince Edward Island	Low	210	2,780	3,880				
ESP								
Barron County	Normal				<1.21	<121	<27.6	
Red Wing	Normal				<0.839	<17.3	<16.4	
RDF fired								
ESP								
Akron	Normal				55.9	240	633	
Albany	Normal				1,570	11,300	34,900	
Niagara	Normal						748	

[a] One test run only.

[b] Not corrected to dry standard conditions.

Acid gases in English units

7-82 Summary of Hydrogen Chloride Emissions From MWC Facilities

7-83 Summary of Hydrogen Fluoride Emissions From MWC Facilities

7-84 Summary of Sulfur Trioxide Emissions From MWC Facilities

TABLE 7-82. SUMMARY OF HYDROGEN CHLORIDE EMISSIONS FROM MWC FACILITIES

Facility name	Test condition	Emissions upstream from control device		Emissions downstream from control device		Control effi- ciency, %
		ppmdv at 12% CO_2	lb/ton feed	ppmdv at 12% CO_2	lb/ton feed	
Mass burn						
Waterwall						
ESP						
Hampton (1981)	Normal			179	2.20	
Hampton (1982)	Normal			268	3.78	
Tulsa (Unit 1)	Normal			421	5.03	
Tulsa (Unit 2)	Normal			402	5.19	
CYC/FF						
Gallatin	Normal	477	5.27			
ESP/WS						
Kure	Normal	1,010	12.6	211	1.89	79.1
SD/ESP						
Munich	MSW only	546	6.25	27.0	0.319	95.1
CYC/DI/ESP/FF						
Malmo	Normal	742	12.9	211		71.6
WSH/DI/FF						
Quebec	110	482		3.99		99.2
Quebec	125	498		10.1		98.0
Quebec	140	422		28.6		92.5
Quebec	200	429		104		76.9
Wurzburg	Normal			52.0	0.464	
SD/FF						
Marion County	Normal			12.0	0.159	
Quebec	140	414		36.5		91.2
Quebec	140 & R.	476		41.8		91.2
Refractory						
ESP						
Philadelphia (NW1)	Normal			140		
Philadelphia (NW2)	Normal			64.8		
CYC						
Mayport	MSW/waste oil			308	5.57	
SD/FF						
Tsushima	Normal	313	2.63	7.50	0.062	97.6
Starved air						
No control device						
Dyersburg	Normal	159	2.08			
Prince Edward Island	Normal	716	8.85			
Prince Edward Island	Long	706	8.26			
Prince Edward Island	High	768	8.96			
Prince Edward Island	Low	627	7.86			
ESP						
Barron County	Normal			457	5.67	
Red Wing	Normal			1,270	16.6	
RDF fired						
ESP						
Akron	Normal			447	3.35	
Albany	Normal			348	5.13	
Niagara	Normal				5.08	
CYC/ESP						
Wright Pat. AFB	Dense RDF	95.9				
CYC/DI/ESP/FF						
Malmo	RDF	776	15.8			

TABLE 7-83. SUMMARY OF HYDROGEN FLUORIDE EMISSIONS FROM MWC FACILITIES

		Emissions upstream from control device		Emissions downstream from control device		
Facility name	Test condition	ppmdv at 12% CO_2	lb/ton feed	ppmdv at 12% CO_2	lb/ton feed	Control efficiency, %
Mass burn						
Waterwall						
ESP						
Hampton (1982)	Normal			1.30	0.010	
Tulsa (Unit 1)	Normal			7.21	0.047	
Tulsa (Unit 2)	Normal			6.27	0.044	
CYC/FF						
Gallatin	Normal	5.18	0.031			
ESP/WS						
Kure	Normal	2.96	0.018	0.935	0.006	68.4
Refractory						
SD/FF						
Tsushima	Normal	1.20	0.005	0.620	0.003	48.3
Starved air						
No control device						
Dyersburg	Normal	1.10	0.008			
Prince Edward Island	Normal	12.0	0.081			
Prince Edward Island	Long	10.8	0.068			
Prince Edward Island	High	15.6	0.099			
Prince Edward Island	Low	12.0	0.083			
RDF fired						
ESP						
Akron	Normal			2.12	0.009	

TABLE 7-84. SUMMARY OF SULFUR TRIOXIDE EMISSIONS FROM MWC FACILITIES

Facility name	Test condition	Emissions upstream from control device		Emissions downstream from control device		Control efficiency, %
		ppmdv at 12% CO_2	lb/ton feed	ppmdv at 12% CO_2	lb/ton feed	
Mass burn						
Waterwall						
ESP						
Tulsa (Unit 1)	Normal			10.1	0.167	
Tulsa (Unit 2)	Normal			9.76	0.173	
CYC/FF						
Gallatin	Normal	85.3	2.07	44.5	1.66	47.8
ESP/WS						
Kure	Normal	5.58	0.148	3.96	0.116	29.0
SD/ESP						
Munich[a]	MSW only	92.0	2.31	21.7	0.562	76.4

[a] This data represents a combined SO_2 and SO_3 value because separate values were not reported.

PCDD in English units

7-85 Summary of 2,3,7,8-Tetrachlorodibenzo-p-dioxin Emissions From MWC Facilities

7-86 Summary of Total Tetrachlorodibenzo-p-dioxin Emissions From MWC Facilities

7-87 Summary of Total Pentachlorodibenzo-p-dioxin Emissions From MWC Facilities

7-88 Summary of Total Hexachlorodibenzo-p-dioxin Emissions From MWC Facilities

7-89 Summary of Total Heptachlorodibenzo-p-dioxin Emissions From MWC Facilities

7-90 Summary of Total Octachlorodibenzo-p-dioxin Emissions From MWC Facilities

7-91 Summary of Tetra- Through Octachlorodibenzo-p-dioxin Emissions From MWC Facilities

7-92 Summary of Total Measured Chlorodibenzo-p-dioxin Emissions From MWC Facilities

TABLE 7-85. SUMMARY OF 2,3,7,8-TETRACHLORODIBENZO-p-DIOXIN EMISSIONS FROM MWC FACILITIES

		Emissions upstream from control device			Emissions downstream from control device			
Facility name	Test condition	$\times 10^{-10}$ gr/dscf	$\times 10^{-10}$ gr/dscf at 12% CO_2	$\times 10^{-10}$ lb/ton feed	$\times 10^{-10}$ gr/dscf	$\times 10^{-10}$ gr/dscf at 12% CO_2	$\times 10^{-10}$ lb/ton feed	Control efficiency, %
Mass burn								
Waterwall								
ESP								
Chicago	Normal				1.79	2.40	42.0	
Hampton (1982)	Normal				275	273	5,790	
Hampton (1983)	Normal				140	130	2,900	
Hampton (1984)	Normal				85.7	153	1,780	
N. Andover[a]	Normal	7.3	8.74		2.32	2.93		66.5
Peekskill (4/85)	Normal						23.4	
Saugus	Normal				6.26	7.43		
Tulsa (Units 1 and 2)	Normal				0.360	0.441	7.95	
Umea, fall	Normal					2.62		
Umea, fall	Low temp					2.10		
Umea, spring	Normal					0.524		
WSH/DI/FF								
Wurzburg	Normal				0.052	0.079	1.02	
SD/FF								
Marion County	Normal					0.354	7.42	
Refractory								
ESP								
Philadelphia (NW1)	Normal				26.4	59.8		
Philadelphia (NW2)	Normal				21.1	53.9		
CYC								
Mayport	MSW/waste oil				7.29	11.4	412	
Starved air								
No control device								
Cattaraugus County	Normal	2.36						
Dyersburg	Normal	3.93	6.71	130				
ESP								
Red Wing	Normal				<0.765	<1.22	<23.5	
RDF fired								
ESP								
Akron	Normal				43.0	63.6	719	
Albany	Normal				1.81	2.28	51.4	

[a] Outlet values which represent the average of test runs 3, 4, and 5 were used to obtain a control efficiency value for simultaneous test runs. Inlet runs 1 and 2 were not analyzed due to sampling difficulties.

TABLE 7-86. SUMMARY OF TOTAL TETRACHLORODIBENZO-p-DIOXIN EMISSIONS FROM MWC FACILITIES

Facility name	Test condition	Emissions upstream from control device			Emissions downstream from control device			Control efficiency, %
		$\times 10^{-10}$ gr/dscf	$\times 10^{-10}$ gr/dscf at 12% CO_2	$\times 10^{-10}$ lb/ton feed	$\times 10^{-10}$ gr/dscf	$\times 10^{-10}$ gr/dscf at 12% CO_2	$\times 10^{-10}$ lb/ton feed	
Mass burn								
Waterwall								
ESP								
Chicago	Normal				27.4	36.7	632	
Hampton (1981)	Normal				1,920	3,500	60,400	
Hampton (1982)	Normal				1,070	1,060	22,500	
Hampton (1983)	Normal				1,010	935	20,800	
Hampton (1984)	Normal				2,820	5,050	58,600	
N. Andover[a]	Normal	62.1	74.3		29	36.6		50.7
Peekskill (4/85)	Normal						236	
Saugus	Normal				117	139		
Tulsa (Units 1 and 2)	Normal				5.76	7.05	127	
Umea, fall	Normal					226		
Umea, fall	Low temp					283		
Umea, spring	Normal					<52.4		
WSH/DI/FF								
Quebec[b]	110	69.9	118		0.0			
Quebec[b]	125	194	314		0.0			
Quebec[b]	140	258	414		0.0			
Quebec[b]	200	106	173		0.0			
Wurzburg	Normal				5.86	8.35	108	
SD/FF								
Marion County	Normal					0.852	17.9	
Quebec[b]	140	141	204		0.0			
Quebec	140 & R.	212	340		0.174	0.279		99.9
Refractory								
ESP								
Philadelphia (NW1)	Normal				728	1,650		
Philadelphia (NW2)	Normal				626	1,600		
CYC								
Mayport	MSW/waste oil				15.6	24.3	904	
Starved air								
No control device								
Cattaraugus County	Normal	35.4						
Dyersburg	Normal	48.9	83.5	1,620				
Prince Edward Island	Normal	8.5	13.3	280				
Prince Edward Island	Long	13.9	22.3	400				
Prince Edward Island	High	3.66	4.44	80.0				
Prince Edward Island	Low	7.2	13.3	280				
ESP								
Red Wing	Normal				121	191	3,690	
RDF fired								
ESP								
Akron	Normal				760	1,130	12,700	
Albany	Normal				68.9	87.0	1,960	
Hamilton-Wentworth[c]	F/None				1,780	2,580		
Hamilton-Wentworth[d]	F/Low back				2,530	2,450		
Hamilton-Wentworth	F/Back				2,100	2,490		

(continued)

TABLE 7-86. (continued)

		Emissions upstream from control device			Emissions downstream from control device			
Facility name	Test condition	$\times 10^{-10}$ gr/dscf	$\times 10^{-10}$ gr/dscf at 12% CO_2	$\times 10^{-10}$ lb/ton feed	$\times 10^{-10}$ gr/dscf	$\times 10^{-10}$ gr/dscf at 12% CO_2	$\times 10^{-10}$ lb/ton feed	Control efficiency, %
Hamilton-Wentworth[c]	F/Back, low front				10,600	15,300		
Hamilton-Wentworth[c]	H/None				2,360	5,240		
Hamilton-Wentworth[c]	H/Low back				1,760	3,060		
CYC/ESP								
Wright Pat. AFB	Normal				9.61	15.2	430	

[a] Outlet values which represent the average of test runs 3, 4, and 5 were used to obtain a control efficiency value for simultaneous test runs. Inlet runs 1 and 2 were not analyzed due to sampling difficulties.

[b] A 0.0 indicates below detection limit (values of detection limit not yet received).

[c] Average of two test runs.

[d] One test run only.

TABLE 7-87. SUMMARY OF TOTAL PENTACHLORODIBENZO-p-DIOXIN EMISSIONS FROM MWC FACILITIES

Facility name	Test condition	Emissions upstream from control device $\times 10^{-10}$ gr/dscf	 $\times 10^{-10}$ gr/dscf at 12% CO_2	 $\times 10^{-10}$ lb/ton feed	Emissions downstream from control device $\times 10^{-10}$ gr/dscf	 $\times 10^{-10}$ gr/dscf at 12% CO_2	 $\times 10^{-10}$ lb/ton feed	Control efficiency, %
Mass burn								
Waterwall								
ESP								
Hampton (1981)	Normal				2,450	4,450	76,800	
Hampton (1983)	Normal				5,240	4,880	109,000	
Hampton (1984)	Normal				6,600	11,800	137,000	
N. Andover^a	Normal	106	127		39.9	50.3		60.3
Peekskill (4/85)	Normal						234	
Saugus	Normal				130	155		
Tulsa (Units 1 and 2)	Normal				10.7	13.1	235	
Umea, fall	Normal					278		
Umea, fall	Low temp					420		
Umea, spring	Normal					257		
WSH/DI/FF^e								
Quebec^b	110	154	259		0.0			
Quebec^b	125	409	662		0.0			
Quebec^b	140	419	671		0.0			
Quebec^b	200	272	444		0.0			
Wurzburg	Normal				7.78	11.1	144	
SD/FF								
Marion County	Normal					0.232	4.85	
Quebec^b	140	302	436		0.0			
Quebec^b	140 & R.	390	622		0.0			
Refractory								
ESP								
Philadelphia (NW1)	Normal				2,050	4,640		
Philadelphia (NW2)	Normal				1,780	4,540		
Starved air								
No control device								
Cattaraugus County	Normal	46.3						
Prince Edward Island	Normal	31.3	48.9	840				
Prince Edward Island	Long	41.7	66.7	1,100				
Prince Edward Island	High	25.6	31.1	460				
Prince Edward Island	Low	19.2	35.6	640				
ESP								
Red Wing	Normal				752	1,190	23,000	
RDF fired								
ESP								
Albany	Normal				581	734	16,600	
Hamilton-Wentworth^c	F/None				1,470	2,140		
Hamilton-Wentworth^d	F/Low back				2,800	2,710		
Hamilton-Wentworth	F/Back				2,460	2,880		
Hamilton-Wentworth^c	F/Back, low front				7,690	11,400		
					2,490	5,690		
Hamilton-Wentworth^c	H/None				2,670	4,370		
Hamilton-Wentworth^c	H/Low back							

(continued)

TABLE 7-87. (continued)

Facility name	Test condition	Emissions upstream from control device $\times 10^{-10}$ gr/dscf	$\times 10^{-10}$ gr/dscf at 12% CO_2	$\times 10^{-10}$ lb/ton feed	Emissions downstream from control device $\times 10^{-10}$ gr/dscf	$\times 10^{-10}$ gr/dscf at 12% CO_2	$\times 10^{-10}$ lb/ton feed	Control efficiency, %
CYC/ESP								
Wright Pat. AFB	Normal				1.62	2.55	72.1	

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[a] Outlet values which represent the average of test runs 3, 4, and 5 were used to obtain a control efficiency value for simultaneous test runs.

[b] Inlet runs 1 and 2 were not analyzed due to sampling difficulties.

[c] A 0.0 indicates below detection limit (values of detection limit not yet received).

[d] Average of two test runs.

[e] One test run only.

TABLE 7-88. SUMMARY OF TOTAL HEXACHLORODIBENZO-p-DIOXIN EMISSIONS FROM MWC FACILITIES

		Emissions upstream from control device			Emissions downstream from control device			
Facility name	Test condition	$\times 10^{-10}$ gr/dscf	$\times 10^{-10}$ gr/dscf at 12% CO_2	$\times 10^{-10}$ lb/ton feed	$\times 10^{-10}$ gr/dscf	$\times 10^{-10}$ gr/dscf at 12% CO_2	$\times 10^{-10}$ lb/ton feed	Control efficiency, %
Mass burn								
Waterwall								
ESP								
Chicago	Normal				71.4	95.5	1,650	
Hampton (1981)	Normal				3,850	6,990	121,000	
Hampton (1983)	Normal				2,230	2,070	46,400	
Hampton (1984)	Normal				7,780	13,900	162,000	
N. Andover[a]	Normal	160	192		81.7	103		46.4
Peekskill (4/85)	Normal						320	
Saugus	Normal				127	151		
Tulsa (Units 1 and 2)	Normal				18.2	22.3	401	
Umea, fall	Normal					168		
Umea, fall	Low temp					430		
Umea, spring	Normal					288		
WSH/DI/FF								
Quebec	110	409	680		0.170	0.288		>99.9
Quebec[b]	125	1,130	1,840		0.0			
Quebec[b]	140	1,000	1,610		0.0			
Quebec	200	694	1,140		7.07	11.6		99.0
Wurzburg	Normal				9.75	13.9	181	
SD/FF								
Marion County	Normal					0.481	10.1	
Quebec[b]	140	822	1,190		0.0			
Quebec	140 & R.	1,120	1,790		0.407	0.649		>99.9
Refractory								
ESP								
Philadelphia (NW1)	Normal				5,330	12,100		
Philadelphia (NW2)	Normal				1,570	4,010		
Starved air								
No control device								
Cattaraugus County	Normal	58.6						
Prince Edward Island	Normal	55.9	88.9	1,560				
Prince Edward Island	Long	60.2	97.7	1,600				
Prince Edward Island	High	35.8	44.4	760				
Prince Edward Island	Low	37.8	71.1	1,380				
ESP								
Red Wing	Normal				1,310	2,080	40,100	
RDF fired								
ESP								
Albany	Normal				492	622	14,000	
Hamilton-Wentworth[c]	F/None				1,580	2,270		
Hamilton-Wentworth[d]	F/Low back				2,090	2,010		
Hamilton-Wentworth	F/Back				2,880	3,450		
Hamilton-Wentworth[c]	F/Back, low front				5,330	7,870		
Hamilton-Wentworth[c]	H/None				2,890	6,120		
Hamilton-Wentworth[c]	H/Low back				3,240	5,680		

(continued)

TABLE 7-88. (continued)

Facility name	Test condition	Emissions upstream from control device $\times 10^{-10}$ gr/dscf	$\times 10^{-10}$ gr/dscf at 12% CO_2	$\times 10^{-10}$ lb/ton feed	Emissions downstream from control device $\times 10^{-10}$ gr/dscf	$\times 10^{-10}$ gr/dscf at 12% CO_2	$\times 10^{-10}$ lb/ton feed	Control efficiency, %
CYC/ESP								
Wright Pat. AFB	Normal				10.9	17.3	487	

[a] Outlet values which represent the average of test runs 3, 4, and 5 were used to obtain a control efficiency value for simultaneous test runs. Inlet runs 1 and 2 were not analyzed due to sampling difficulties.

[b] A 0.0 indicates below detection limit (values of detection limit not yet received).

[c] Average of two test runs.

[d] One test run only.

TABLE 7-89. SUMMARY OF TOTAL HEPTACHLORODIBENZO-p-DIOXIN EMISSIONS FROM MWC FACILITIES

Facility name	Test condition	Emissions upstream from control device $\times10^{-10}$ gr/dscf	 $\times10^{-10}$ gr/dscf at 12% CO_2	 $\times10^{-10}$ lb/ton feed	Emissions downstream from control device $\times10^{-10}$ gr/dscf	 $\times10^{-10}$ gr/dscf at 12% CO_2	 $\times10^{-10}$ lb/ton feed	Control efficiency, %
Mass burn								
Waterwall								
ESP								
Chicago	Normal				33.1	44.3	765	
Hampton (1981)	Normal				4,630	8,420	146,000	
Hampton (1983)	Normal				699	650	14,500	
Hampton (1984)	Normal				7,040	12,600	146,000	
N. Andover[a]	Normal	131	157		94.4	119		24.2
Peekskill (4/85)	Normal						460	
Saugus	Normal				110	131		
Tulsa (Units 1 and 2)	Normal				15.8	19.3	348	
Umea, fall	Normal					94.4		
Umea, fall	Low temp					283		
Umea, spring	Normal					294		
WSH/DI/FF								
Quebec[b]	110	551	929		0.0			
Quebec[b]	125	1,340	2,180		0.0			
Quebec[b]	140	1,100	1,750		0.0			
Quebec	200	1,010	1,660		7.07	11.6		99.3
Wurzburg	Normal				13.2	18.8	244	
SD/FF								
Marion County	Normal					0.804	16.8	
Quebec[b]	140	1,210	1,750		0.0			
Quebec	140 & R.	1,150	1,830		0.467	0.747		>99.9
Refractory								
ESP								
Philadelphia (NW1)	Normal				1,750	3,960		
Philadelphia (NW2)	Normal				685	1,750		
Starved air								
No control device								
Cattaraugus County	Normal	55.1						
Prince Edward Island	Normal	88.0	137	2,440				
Prince Edward Island	Long	75.0	120	2,060				
Prince Edward Island	High	69.3	84.4	1,340				
Prince Edward Island	Low	81.5	152	2,840				
ESP								
Red Wing	Normal				1,230	1,950	37,600	
RDF fired								
ESP								
Albany	Normal				451	569	12,800	
Hamilton-Wentworth[c]	F/None				401	568		
Hamilton-Wentworth[d]	F/Low back				2,220	2,140		
Hamilton-Wentworth[c]	F/Back				1,290	2,230		
Hamilton-Wentworth[c]	F/Back, low front				1,510	2,360		
Hamilton-Wentworth[c]	H/None				1,020	2,270		
Hamilton-Wentworth[c]	H/Low back				2,000	3,630		

(continued)

TABLE 7-89. (continued)

Facility name	Test condition	Emissions upstream from control device			Emissions downstream from control device			Control efficiency, %
		$\times 10^{-10}$ gr/dscf	$\times 10^{-10}$ gr/dscf at 12% CO_2	$\times 10^{-10}$ lb/ton feed	$\times 10^{-10}$ gr/dscf	$\times 10^{-10}$ gr/dscf at 12% CO_2	$\times 10^{-10}$ lb/ton feed	
CYC/ESP Wright Pat. AFB	Normal				81.2	128	3,620	

[a] Outlet values which represent the average of test runs 3, 4, and 5 were used to obtain a control efficiency value for simultaneous test runs. Inlet runs 1 and 2 were not analyzed due to sampling difficulties.

[b] A 0.0 indicates below detection limit (values of detection limit not yet received).

[c] Average of two test runs.

[d] One test run only.

TABLE 7-90. SUMMARY OF TOTAL OCTACHLORODIBENZO-p-DIOXIN EMISSIONS FROM MWC FACILITIES

		Emissions upstream from control device			Emissions downstream from control device			
Facility name	Test condition	$\times 10^{-10}$ gr/dscf	$\times 10^{-10}$ gr/dscf at 12% CO_2	$\times 10^{-10}$ lb/ton feed	$\times 10^{-10}$ gr/dscf	$\times 10^{-10}$ gr/dscf at 12% CO_2	$\times 10^{-10}$ lb/ton feed	Control efficiency, %
Mass burn								
Waterwall								
ESP								
Chicago	Normal				11.1	14.8	255	
Hampton (1981)	Normal				1,220	2,220	38,600	
Hampton (1983)	Normal				179	167	3,720	
Hampton (1984)	Normal				1,790	3,210	37,400	
N. Andover[a]	Normal	106	127		76.3	96.1		24.1
Peekskill (4/85)	Normal						739	
Saugus	Normal				137	163		
Tulsa (Units 1 and 2)	Normal				17.2	21.0	378	
Umea, fall	Normal					62.9		
Umea, fall	Low temp					73.4		
Umea, spring	Normal					278		
WSH/DI/FF								
Quebec	110	458	778		0.255	0.431		99.9
Quebec[b]	125	1,060	1,730		0.0			
Quebec[b]	140	893	1,420		0.0			
Quebec	200	760	1,250		2.77	4.54		99.6
Wurzburg	Normal				31.2	44.4	578	
SD/FF								
Marion County	Normal					2.57	53.9	
Quebec[b]	140	964	1,390		0.0			
Quebec[b]	140 & R.	893	1,430		0.0			
Refractory								
ESP								
Philadelphia (NW1)	Normal				704	1,590		
Philadelphia (NW2)	Normal				283	723		
Starved air								
No control device								
Cattaraugus County	Normal	59.9						
Prince Edward Island	Normal	122	191	3,440				
Prince Edward Island	Long	105	169	2,840				
Prince Edward Island	High	94.6	116	1,900				
Prince Edward Island	Low	149	276	5,180				
ESP								
Red Wing	Normal				834	1,320	25,500	
RDF fired								
ESP								
Albany	Normal				75.5	95.3	2,150	
Hamilton-Wentworth[c]	F/None				423	612		
Hamilton-Wentworth[d]	F/Low back				1,150	1,140		
Hamilton-Wentworth	F/Back				878	1,350		
Hamilton-Wentworth[c]	F/Back, low front				1,180	1,790		
Hamilton-Wentworth[c]	H/None				778	1,750		
Hamilton-Wentworth[c]	H/Low back				1,910	3,360		

(continued)

TABLE 7-90. (continued)

Facility name	Test condition	Emissions upstream from control device $\times 10^{-10}$ gr/dscf	 $\times 10^{-10}$ gr/dscf at 12% CO_2	 $\times 10^{-10}$ lb/ton feed	Emissions downstream from control device $\times 10^{-10}$ gr/dscf	 $\times 10^{-10}$ gr/dscf at 12% CO_2	 $\times 10^{-10}$ lb/ton feed	Control efficiency, %
CYC/ESP Wright Pat. AFB	Normal				45.4	71.8	2,030	

[a] Outlet values which represent the average of test runs 3, 4, and 5 were used to obtain a control efficiency value for simultaneous test runs. Inlet runs 1 and 2 were not analyzed due to sampling difficulties.

[b] A 0.0 indicates below detection limit (values of detection limit not yet received).

[c] Average of two test runs.

[d] One test run only.

TABLE 7-91. SUMMARY OF TETRA- THROUGH OCTACHLORODIBENZO-p-DIOXIN EMISSIONS FROM MWC FACILITIES

		Emissions upstream from control device			Emissions downstream from control device			
Facility name	Test condition	$\times10^{-10}$ gr/dscf	$\times10^{-10}$ gr/dscf at 12% CO_2	$\times10^{-10}$ lb/ton feed	$\times10^{-10}$ gr/dscf	$\times10^{-10}$ gr/dscf at 12% CO_2	$\times10^{-10}$ lb/ton feed	Control efficiency, %
Mass burn								
Waterwall								
ESP								
Hampton (1981)	Normal				14,100	25,600	442,000	
Hampton (1983)	Normal				9,350	8,700	194,000	
Hampton (1984)	Normal				26,000	46,600	540,000	
N. Andover[a]	Normal	564	677		327	406		40.1
Peekskill (4/85)	Normal						19,300	
Saugus	Normal				623	739		
Tulsa (Units 1 and 2)	Normal				67.6	82.7	1,490	
Umea, fall	Normal					830		
Umea, fall	Low temp					1,490		
Umea, spring	Normal					1,170		
WSH/DI/FF								
Quebec	110	1,650	2,780		0.426	0.720		>99.9
Quebec[b]	125	4,140	6,710		0.0			
Quebec[b]	140	3,670	5,870		0.0			
Quebec	200	2,840	4,670		16.9	27.8		99.4
Wurzburg	Normal				67.8	96.6	1,250	
SD/FF								
Marion County	Normal					4.94	103	
Quebec[b]	140	3,450	4,970		0.0			
Quebec	140 & R.	3,760	6,000		1.04	1.66		>99.9
Refractory								
ESP								
Philadelphia (NW1)	Normal				10,300	23,300		
Philadelphia (NW2)	Normal				4,810	12,600		
Starved air								
No control device								
Cattaraugus County	Normal	255						
Prince Edward Island	Normal	304	476	8,560				
Prince Edward Island	Long	297	476	8,000				
Prince Edward Island	High	226	276	4,560				
Prince Edward Island	Low	295	547	10,300				
ESP								
Red Wing	Normal				4,260	6,730	130,000	
RDF fired								
ESP								
Albany	Normal				1,670	2,110	47,600	
Hamilton-Wentworth[c]	F/None				5,650	8,170		
Hamilton-Wentworth[d]	F/Low back				10,800	10,400		
Hamilton-Wentworth[c]	F/Back				9,610	12,400		
Hamilton-Wentworth[c]	F/Back, low front				26,400	38,700		
Hamilton-Wentworth[c]	H/None				9,530	21,100		
Hamilton-Wentworth[c]	H/Low back				11,600	20,100		

(continued)

TABLE 7-91. (continued)

		Emissions upstream from control device			Emissions downstream from control device			
Facility name	Test condition	$\times10^{-10}$ gr/dscf	$\times10^{-10}$ gr/dscf at 12% CO_2	$\times10^{-10}$ lb/ton feed	$\times10^{-10}$ gr/dscf	$\times10^{-10}$ gr/dscf at 12% CO_2	$\times10^{-10}$ lb/ton feed	Control efficiency, %
CYC/ESP								
Wright Pat. AFB	Normal				178	235	7,970	

[a] Outlet values which represent the average of test runs 3, 4, and 5 were used to obtain a control efficiency value for simultaneous test runs. Inlet runs 1 and 2 were not analyzed due to sampling difficulties.

[b] A 0.0 indicates below detection limit (values of detection limit not yet received).

[c] Average of two test runs.

[d] One test run only.

TABLE 7-92. SUMMARY OF TOTAL MEASURED CHLORODIBENZO-p-DIOXIN EMISSIONS FROM MWC FACILITIES

Facility name	Test condition	Emissions upstream from control device: $\times 10^{-10}$ gr/dscf	Emissions upstream from control device: $\times 10^{-10}$ gr/dscf at 12% CO_2	Emissions upstream from control device: $\times 10^{-10}$ lb/ton feed	Emissions downstream from control device: $\times 10^{-10}$ gr/dscf	Emissions downstream from control device: $\times 10^{-10}$ gr/dscf at 12% CO_2	Emissions downstream from control device: $\times 10^{-10}$ lb/ton feed	Control efficiency, %
Mass burn								
Waterwall								
ESP								
Chicago[a]								
Hampton (1981)[b]	Normal				143	191	3,350	
Hampton (1982)[c]	Normal				14,100	25,600	442,000	
Hampton (1983)[b]	Normal				1,070	1,060	22,500	
Hampton (1984)[b]	Normal				9,350	8,700	194,000	
N. Andover[d]	Normal				26,000	46,600	540,000	
Peekskill (4/85)[b]	Normal	616	739		345	435		41.1
Saugus[b]	Normal				623	739	19,300	
Tulsa (Units 1 and 2)[b]	Normal	Normai				67.6	82.7	1,490
Umea, fall[b]	Normal					830		
Umea, fall[b]	Low temp					1,490		
Umea, spring[b]	Normal					1,170		
WSH/DI/FF								
Quebec[b]	110	1,650	2,780		0.426	0.720		>99.9
Quebec[e f]	125	4,140	6,710		0.0			
Quebec[e f]	140	3,670	5,870		0.0			
Quebec[e]	200	2,840	4,670		16.9	27.8		99.4
Wurzburg[b]	Normal				68.5	96.5	1,250	
SD/FF								
Marion County[b]	Normal					4.94	103	
Quebec[e f]	140	3,450	4,970		0.0			
Quebec[e]	140 & R.	3,760	6,000		1.04	1.66		>99.9
Refractory								
ESP								
Philadelphia (NW1)[b]	Normal				10,300	23,300		
Philadelphia (NW2)[b]	Normal				4,810	12,300		
CYC								
Mayport[c]	MSW/waste oil				15.6	24.3	904	
EGB								
Pittsfield[b]	Experi-mental	234						
Starved air								
No control device								
Cattaraugus County[b]	Normal	255						
Dyersburg[c]	Normal	48.9	83.5	1,620				
Prince Edward Island[b]	Normal	304	476	8,560				
Prince Edward Island[b]	Long	297	476	8,000				
Prince Edward Island[b]	High	226	276	4,560				
Prince Edward Island[b]	Low	295	547	10,300				
ESP								
Red Wing[b]	Normal				4,260	6,730	130,000	

(continued)

TABLE 7-92. (continued)

Facility name	Test condition	Emissions upstream from control device			Emissions downstream from control device			Control efficiency, %
		$\times 10^{-10}$ gr/dscf	$\times 10^{-10}$ gr/dscf at 12% CO_2	$\times 10^{-10}$ lb/ton feed	$\times 10^{-10}$ gr/dscf	$\times 10^{-10}$ gr/dscf at 12% CO_2	$\times 10^{-10}$ lb/ton feed	
RDF fired								
ESP								
Akron[c]	Normal				760	1,130	12,700	
Albany[b]	Normal				1,670	2,110	47,600	
Hamilton-Wentworth[b] [g]	F/None				5,650	8,170		
Hamilton-Wentworth[b] [h]	F/Low back				10,800	10,400		
Hamilton-Wentworth[g]	F/Back				9,610	12,400		
Hamilton-Wentworth[b] [g]	F/Back, low front[f]				26,400	38,700		
Hamilton-Wentworth[b] [g]	H/None				9,530	21,100		
Hamilton-Wentworth[b] [g]	H/Low back				11,600	20,100		
CYC/ESP								
Wright Pat. AFB[b]	Normal				178	235	7,970	

[a] Sum of tetra- through octachlorodibenzo-p-dioxin without penta.

[b] Sum of tetra- through octachlorodibenzo-p-dioxin.

[c] Tetrachlorodibenzo-p-dioxin only.

[d] Outlet values which represent the average of test runs 3, 4, and 5 were used to obtain a control efficiency value for simultaneous test runs. Inlet runs 1 and 2 were not analyzed due to sampling difficulties.

[e] Presented as polychlorodibenzo-p-dioxin in test report.

[f] A 0.0 indicates below detection limit (values of detection limit not yet received).

[g] Average of two test runs.

[h] One test run only.

Isomer-specific PCDD in English units

7-93 Summary of 2,3,7,8-Substituted and Total Tetrachlorodibenzo-p-dioxin Emissions from MWC Facilities

7-94 Summary of 2,3,7,8-Substituted and Total Pentachlorodibenzo-p-dioxin Emissions from MWC Facilities

7-95 Summary of 2,3,7,8-Substituted and Total Hexachlorodibenzo-p-dioxin Emissions from MWC Facilities

7-96 Summary of 2,3,7,8-Substituted and Total Heptachlorodibenzo-p-dioxin Emissions from MWC Facilities

TABLE 7-93. SUMMARY OF 2,3,7,8-SUBSTITUTED AND TOTAL TETRACHLORODIBENZO-P-DIOXIN EMISSIONS FROM MWC FACILITIES

		Emissions upstream from control device		Emissions downstream from control device	
Facility name	Test condition	2,3,7,8-TCDD, x10^{-10} gr/dscf at 12% CO_2	Total TCDD, x10^{-10} gr/dscf at 12% CO_2	2,3,7,8-TCDD, x10^{-10} gr/dscf at 12% CO_2	Total TCDD, x10^{-10} gr/dscf at 12% CO_2
Mass burn					
Waterwall					
ESP					
Chicago	Normal			2.4	36.7
Hampton (1982)	Normal			273	1,060
Hampton (1983)	Normal			130	933
Hampton (1984)	Normal			153	5,050
N. Andover	Normal	8.74	74.3	2.93	36.6
Saugus	Normal			7.43	139
Tulsa (Units 1 and 2)	Normal			0.441	7.05
Umea, fall	Normal			2.62	226
Umea, fall	Low temp			2.10	283
Umea, spring	Normal			0.524	<52.4
WSH/DI/FF					
Wurzburg	Normal			0.079	8.35
SD/FF					
Marion County	Normal			0.354	0.852
Refractory					
ESP					
Philadelphia (NW1)	Normal			59.8	1,650
Philadelphia (NW2)	Normal			53.9	1,600
CYC					
Mayport	MSW/waste oil			11.4	24.3
Starved air					
No control device					
Cattaraugus County[a]	Normal	2.36	35.4		
Dyersburg	Normal	6.71	83.5		
ESP					
Red Wing	Normal			<1.22	191
RDF fired					
ESP					
Akron	Normal			63.6	1,130
Albany	Normal			2.28	87

[a] Not corrected to 12 percent CO_2.

TABLE 7-94. SUMMARY OF 2,3,7,8-SUBSTITUTED AND TOTAL PENTACHLORODIBENZO-P-DIOXIN EMISSIONS FROM MWC FACILITIES

Facility name	Test condition	Emissions upstream from control device		Emissions downstream from control device	
		1,2,3,7,8-PeCDD, $\times 10^{-10}$ gr/dscf at 12% CO_2	Total PeCDD, $\times 10^{-10}$ gr/dscf at 12% CO_2	1,2,3,7,8-PeCDD, $\times 10^{-10}$ gr/dscf at 12% CO_2	Total PeCDD, $\times 10^{-10}$ gr/dscf at 12% CO_2
Mass burn					
Waterwall					
ESP					
N. Andover	Normal	4.37	127	5.77	50.3
Saugus	Normal			14.9	155
Tulsa (Units 1 and 2)	Normal			0.83	13.1
Umea, fall	Normal			13.1	278
Umea, fall	Low temp			16.6	420
Umea, spring	Normal			12.7	257
WSH/DI/FF					
Wurzburg	Normal			0.874	11.1
SD/FF					
Marion County	Normal			0.039	0.232
Refractory					
ESP					
Philadelphia (NW1)	Normal			358	4,640
Philadelphia (NW2)	Normal			398	4,540
Starved air					
ESP					
Red Wing	Normal			55.9	1,190

TABLE 7-95. SUMMARY OF 2,3,7,8-SUBSTITUTED AND TOTAL HEXACHLORODIBENZO-P-DIOXIN EMISSIONS FROM MWC FACILITIES

Facility name	Test condition	Emissions upstream from control device				Emissions downstream from control device			
		1,2,3,4,7,8-HxCDD, $\times 10^{-10}$ gr/dscf at 12% CO_2	1,2,3,6,7,8-HxCDD, $\times 10^{-10}$ gr/dscf at 12% CO_2	1,2,3,7,8,9-HxCDD, $\times 10^{-10}$ gr/dscf at 12% CO_2	Total HxCDD, $\times 10^{-10}$ gr/dscf at 12% CO_2	1,2,3,4,7,8-HxCDD, $\times 10^{-10}$ gr/dscf at 12% CO_2	1,2,3,6,7,8-HxCDD, $\times 10^{-10}$ gr/dscf at 12% CO_2	1,2,3,7,8,9-HxCDD, $\times 10^{-10}$ gr/dscf at 12% CO_2	Total HxCDD, $\times 10^{-10}$ gr/dscf at 12% CO_2
Mass burn									
Waterwall									
ESP									
N. Andover	Normal	4.37	13.1	8.74	192	6.16	9.22	6.51	103
Saugus	Normal					8.30	14.0	0.0	151
Tulsa (Units 1 and 2)	Normal					0.656	1.62	0.00	22.3
Umea, fall	Normal					8.30	19.2	6.99	168
Umea, fall	Low temp					26.7	48.1	20.1	430
Umea, spring	Normal					12.2	30.6	10.5	288
WSH/DI/FF									
Wurzburg	Normal					0.350	0.830	0.524	13.9
SD/FF									
Marion County	Normal					0.031	0.035	0.035	0.481
Refractory									
ESP									
Philadelphia (NW1)	Normal					1,310			12,100
Philadelphia (NW2)	Normal					503			4,010
Starved air									
ESP									
Red Wing	Normal					75.6	211	302	2,080

TABLE 7-96. SUMMARY OF 2,3,7,8-SUBSTITUTED AND TOTAL HEPTACHLORODIBENZO-P-DIOXIN EMISSIONS FROM MWC FACILITIES

Facility name	Test condition	Emissions upstream from control device: 1,2,3,4,6,7,8-HpCDD $\times 10^{-10}$ gr/dscf at 12% CO_2	Emissions upstream from control device: Total HpCDD, $\times 10^{-10}$ gr/dscf at 12% CO_2	Emissions downstream from control device: 1,2,3,4,6,7,8-HpCDD, $\times 10^{-10}$ gr/dscf at 12% CO_2	Emissions downstream from control device: Total HpCDD, $\times 10^{-10}$ gr/dscf at 12% CO_2
Mass burn					
Waterwall					
ESP					
Tulsa (Units 1 and 2)	Normal			9.61	19.3
WSH/DI/FF					
Wurzburg	Normal			9.61	18.8
SD/FF					
Marion County	Normal			0.603	0.804
Refractory					
ESP					
Philadelphia (NW1)	Normal			2,000	3,960
Philadelphia (NW2)	Normal			878	1,750
Starved air					
ESP					
Red Wing	Normal			983	1,950

PCDF in English units

7-97 Summary of 2,3,7,8-Tetrachlorodibenzofuran Emissions From MWC Facilities

7-98 Summary of Total Tetrachlorodibenzofuran Emissions From MWC Facilities

7-99 Summary of Total Pentachlorodibenzofuran Emissions From MWC Facilities

7-100 Summary of Total Hexachlorodibenzofuran Emissions From MWC Facilities

7-101 Summary of Total Heptachlorodibenzofuran Emissions From MWC Facilities

7-102 Summary of Total Octachlorodibenzofuran Emissions From MWC Facilities

7-103 Summary of Tetra- Through Octachlorodibenzofuran Emissions From MWC Facilities

7-104 Summary of Total Measured Chlorodibenzofuran Emissions From MWC Facilities

TABLE 7-97. SUMMARY OF 2,3,7,8-TETRACHLORODIBENZOFURAN EMISSIONS FROM MWC FACILITIES

Facility name	Test condition	Emissions upstream from control device $\times 10^{-10}$ gr/dscf	 $\times 10^{-10}$ gr/dscf at 12% CO_2	 $\times 10^{-10}$ lb/ton feed	Emissions downstream from control device $\times 10^{-10}$ gr/dscf	 $\times 10^{-10}$ gr/dscf at 12% CO_2	 $\times 10^{-10}$ lb/ton feed	Control efficiency, %
Mass burn								
Waterwall								
ESP								
Hampton (1982)	Normal				319	316	6,710	
Hampton (1984)	Normal				1,090	1,960	22,600	
N. Andover[a,b]	Normal	40.1	48.1		56.5	71.2		
Peekskill (4/85)	Normal						179	
Saugus	Normal				85.7	102		
Tulsa (Units 1 and 2)	Normal				10.4	12.7	229	
Umea, fall	Normal					13.1		
Umea, fall	Low temp					13.6		
Umea, spring	Normal					4.19		
WSH/DI/FF								
Wurzburg	Normal				0.787	1.09	14.2	
SD/FF								
Marion County	Normal					0.734	15.4	
Refractory								
ESP								
Philadelphia (NW1)	Normal				111	251		
Philadelphia (NW2)	Normal				57.7	147		
CYC								
Mayport	MSW/waste oil				44.9	69.9	2,540	
Starved air								
No control device								
Cattaraugus County	Normal	11.8						
ESP								
Red Wing	Normal				161	256	4,940	
RDF fired								
ESP								
Albany	Normal				9.31	11.8	265	

[a] Outlet values which represent the average of test runs 3, 4, and 5 were used to obtain a control efficiency value for simultaneous test runs. Inlet runs 1 and 2 were not analyzed due to sampling difficulties.

[b] An apparent increase in concentration occurred across the control device; however, no reason for this increase was indicated in the test reports.

TABLE 7-98. SUMMARY OF TOTAL TETRACHLORODIBENZOFURAN EMISSIONS FROM MWC FACILITIES

Facility name	Test condition	Emissions upstream from control device: $x10^{-10}$ gr/dscf	Emissions upstream from control device: $x10^{-10}$ gr/dscf at 12% CO_2	Emissions upstream from control device: $x10^{-10}$ lb/ton feed	Emissions downstream from control device: $x10^{-10}$ gr/dscf	Emissions downstream from control device: $x10^{-10}$ gr/dscf at 12% CO_2	Emissions downstream from control device: $x10^{-10}$ lb/ton feed	Control efficiency, %
Mass burn								
Waterwall								
ESP								
Chicago	Normal				392	524	9,060	
Hampton (1981)	Normal				11,000	19,000	344,000	
Hampton (1982)	Normal				1,680	1,670	35,400	
Hampton (1983)	Normal				4,810	4,470	99,800	
Hampton (1984)	Normal				8,390	15,000	174,000	
N. Andover[a,b]	Normal	156	188		215	271		
Peekskill (4/85)	Normal						2,480	
Saugus	Normal				668	794		
Tulsa (Units 1 and 2)	Normal				26.1	31.9	575	
Umea, fall	Normal					451		
Umea, fall	Low temp					456		
Umea, spring	Normal					99.6		
WSH/DI/FF								
Quebec[c]	110	266	449		0.0			
Quebec[c]	125	800	1,300		0.0			
Quebec[c]	140	960	1,540		0.0			
Quebec	200	368	604		0.138	0.228		>99.9
Wurzburg	Normal				29.4	41.9	544	
SD/FF								
Marion County	Normal					1.41	29.5	
Quebec[c]	140	574	827		0.0			
Quebec	140 & R.	689	1,100		0.349	0.560		>99.9
Refractory								
ESP								
Philadelphia (NW1)	Normal				2,110	4,780		
Philadelphia (NW2)	Normal				1,270	3,240		
CYC								
Mayport	MSW/waste oil				91.9	143	5,230	
Starved air								
No control device								
Cattaraugus County	Normal	524						
Dyersburg	Normal	317	541	10,500				
Prince Edward Island	Normal	65.4	103	1,860				
Prince Edward Island	Long	66.7	107	1,780				
Prince Edward Island	High	43.6	53.3	860				
Prince Edward Island	Low	31.2	57.8	1,120				
ESP								
Red Wing	Normal				950	1,510	29,100	
RDF fired								
ESP								
Akron	Normal				2,000	2,970	33,500	
Albany	Normal				162	205	4,630	
Hamilton-Wentworth[d]	F/None				10,700	15,700		

(continued)

TABLE 7-98. (continued)

Facility name	Test condition	Emissions upstream from control device			Emissions downstream from control device			Control efficiency, %
		$\times 10^{-10}$ gr/dscf	$\times 10^{-10}$ gr/dscf at 12% CO_2	$\times 10^{-10}$ lb/ton feed	$\times 10^{-10}$ gr/dscf	$\times 10^{-10}$ gr/dscf at 12% CO_2	$\times 10^{-10}$ lb/ton feed	
Hamilton-Wentworth[e]	F/Low back				15,800	15,300		
Hamilton-Wentworth	F/Back				11,400	13,500		
Hamilton-Wentworth[d]	F/Back, low front				18,700	25,300		
Hamilton-Wentworth[d]	H/None				8,130	18,400		
Hamilton-Wentworth[d]	H/Low back				5,720	10,100		
CYC/ESP								
Wright Pat. AFB	Normal				87.8	139	3,920	

[a] Outlet values which represent the average of test runs 3, 4, and 5 were used to obtain a control efficiency value for simultaneous test runs. Inlet runs 1 and 2 were not analyzed due to sampling difficulties.

[b] An apparent increase in concentration occurred across the control device; however, no reason for this increase was indicated in the test reports.

[c] A 0.0 indicates below detection limit (values of detection limit not yet received).

[d] Average of two test runs.

[e] One test run only.

TABLE 7-99. SUMMARY OF TOTAL PENTACHLORODIBENZOFURAN EMISSIONS FROM MWC FACILITIES

Facility name	Test condition	Emissions upstream from control device			Emissions downstream from control device			Control efficiency, %
		x10^{-10} gr/dscf	x10^{-10} gr/dscf at 12% CO$_2$	x10^{-10} lb/ton feed	x10^{-10} gr/dscf	x10^{-10} gr/dscf at 12% CO$_2$	x10^{-10} lb/ton feed	
Mass burn								
Waterwall								
ESP								
Hampton (1981)	Normal				4,410	8,020	139,000	
Hampton (1983)	Normal				27,100	25,200	562,000	
Hampton (1984)	Normal				11,300	20,200	234,000	
N. Andover$^{a\ b}$	Normal	65.6	78.7		115	145		
Peekskill (4/85)	Normal						1,450	
Saugus	Normal				390	463		
Tulsa (Units 1 and 2)	Normal				11.9	14.6	262	
Umea, fall	Normal					509		
Umea, fall	Low temp					577		
Umea, spring	Normal					225		
WSH/DI/FF								
Quebec^c	110	241	409		0.0			
Quebec^c	125	671	1,100		0.0			
Quebec^c	140	752	1,200		0.0			
Quebec	200	600	987		0.138	0.228		>99.9
Wurzburg	Normal				28.7	40.4	526	
SD/FF								
Marion County	Normal					0.192	4.03	
Quebec^c	140	533	769		0.0			
Quebec	140 & R.	604	967		0.407	0.649		99.9
Refractory								
ESP								
Philadelphia (NW1)	Normal				2,330	5,280		
Philadelphia (NW2)	Normal				1,760	4,490		
Starved air								
No control device								
Cattaraugus County	Normal	241						
Prince Edward Island	Normal	102	160	2,900				
Prince Edward Island	Long	119	191	3,140				
Prince Edward Island	High	83.7	103	1,620				
Prince Edward Island	Low	50.6	93.4	1,760				
ESP								
Red Wing	Normal				1,230	1,950	37,600	
RDF fired								
ESP								
Albany	Normal				133	168	3,780	
Hamilton-Wentworth^d	F/None				7,390	10,900		
Hamilton-Wentworth^e	F/Low back				13,200	12,700		
Hamilton-Wentworth	F/Back				11,800	17,500		
Hamilton-Wentworth^d	F/Back, low front				15,600	21,400		
Hamilton-Wentworth^d	H/None				5,770	12,700		
Hamilton-Wentworth^d	H/Low back				6,470	11,400		

(continued)

TABLE 7-99. (continued)

Facility name	Test condition	Emissions upstream from control device			Emissions downstream from control device			Control efficiency, %
		$\times 10^{-10}$ gr/dscf	$\times 10^{-10}$ gr/dscf at 12% CO_2	$\times 10^{-10}$ lb/ton feed	$\times 10^{-10}$ gr/dscf	$\times 10^{-10}$ gr/dscf at 12% CO_2	$\times 10^{-10}$ lb/ton feed	
CYC/ESP								
Wright Pat. AFB	Normal				30.5	48.1	1,360	

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[a] Outlet values which represent the average of test runs 3, 4, and 5 were used to obtain a control efficiency value for simultaneous test runs. Inlet runs 1 and 2 were not analyzed due to sampling difficulties.

[b] An apparent increase in concentration occurred across the control device; however, no reason for this increase was indicated in the test reports.

[c] A 0.0 indicates below detection limit (values of detection limit not yet received).

[d] Average of two test runs.

[e] One test run only.

TABLE 7-100. SUMMARY OF TOTAL HEXACHLORODIBENZOFURAN EMISSIONS FROM MWC FACILITIES

Facility name	Test condition	Emissions upstream from control device			Emissions downstream from control device			Control efficiency, %
		$\times 10^{-10}$ gr/dscf	$\times 10^{-10}$ gr/dscf at 12% CO_2	$\times 10^{-10}$ lb/ton feed	$\times 10^{-10}$ gr/dscf	$\times 10^{-10}$ gr/dscf at 12% CO_2	$\times 10^{-10}$ lb/ton feed	
Mass burn								
Waterwall								
ESP								
Chicago	Normal				271	362	6,260	
Hampton (1981)	Normal				5,240	9,530	165,000	
Hampton (1983)	Normal				3,060	2,850	63,600	
Hampton (1984)	Normal				9,700	17,400	202,000	
N. Andover[a,b]	Normal	40.1	48.1		77.7	97.9		
Peekskill (4/85)	Normal						1,500	
Saugus	Normal				256	304		
Tulsa (Units 1 and 2)	Normal				6.50	7.96	143	
Umea, fall	Normal					173		
Umea, fall	Low temp					262		
Umea, spring	Normal					225		
WSH/DI/FE								
Quebec[c]	110	165	279		0.0			
Quebec[c]	125	680	1,100		0.0			
Quebec[c]	140	658	1,050		0.0			
Quebec	200	302	497		0.138	0.228		>99.9
Wurzburg	Normal				18.5	26.4	342	
SD/FF								
Marion County	Normal					0.057	1.19	
Quebec[c]	140	489	711		0.0			
Quebec	140 & R.	609	977		0.407	0.649		99.9
Refractory								
ESP								
Philadelphia (NW1)	Normal				5,430	12,300		
Philadelphia (NW2)	Normal				1,370	3,500		
Starved air								
No control device								
Cattaraugus County	Normal	90.5						
Prince Edward Island	Normal	125	195	3,500				
Prince Edward Island	Long	136	218	3,580				
Prince Edward Island	High	116	142	2,260				
Prince Edward Island	Low	67.2	124	2,360				
ESP								
Red Wing	Normal				1,320	2,090	40,300	
RDF fired								
ESP								
Albany	Normal				28.5	361	814	
Hamilton-Wentworth[d]	F/None				843	5,240		
Hamilton-Wentworth[e]	F/Low back				5,110	4,810		
Hamilton-Wentworth	F/Back				5,720	7,430		
Hamilton-Wentworth[d]	F/Back, low front				5,070	6,990		
Hamilton-Wentworth[d]	H/None				3,910	8,740		
Hamilton-Wentworth[d]	H/Low back				4,090	6,990		

(continued)

TABLE 7-100. (continued)

Facility name	Test condition	Emissions upstream from control device $\times10^{-10}$ gr/dscf	$\times10^{-10}$ gr/dscf at 12% CO_2	$\times10^{-10}$ lb/ton feed	Emissions downstream from control device $\times10^{-10}$ gr/dscf	$\times10^{-10}$ gr/dscf at 12% CO_2	$\times10^{-10}$ lb/ton feed	Control efficiency, %
CYC/ESP Wright Pat. AFB	Normal				49.7	78.5	2,210	

[a] Outlet values which represent the average of test runs 3, 4, and 5 were used to obtain a control efficiency value for simultaneous test runs. Inlet runs 1 and 2 were not analyzed due to sampling difficulties.

[b] An apparent increase in concentration occurred across the control device; however, no reason for this increase was indicated in the test reports.

[c] A 0.0 indicates below detection limit (values of detection limit not yet received).

[d] Average of two test runs.

[e] One test run only.

TABLE 7-101. SUMMARY OF TOTAL HEPTACHLORODIBENZOFURAN EMISSIONS FROM MWC FACILITIES

Facility name	Test condition	Emissions upstream from control device $x10^{-10}$ gr/dscf	Emissions upstream from control device $x10^{-10}$ gr/dscf at 12% CO_2	Emissions upstream from control device $x10^{-10}$ lb/ton feed	Emissions downstream from control device $x10^{-10}$ gr/dscf	Emissions downstream from control device $x10^{-10}$ gr/dscf at 12% CO_2	Emissions downstream from control device $x10^{-10}$ lb/ton feed	Control efficiency, %
Mass burn								
Waterwall								
ESP								
Chicago	Normal				32.6	43.7	753	
Hampton (1981)	Normal				5,200	9,460	163,000	
Hampton (1983)	Normal				874	813	18,100	
Hampton (1984)[a,b]	Normal				6,250	11,200	130,000	
N. Andover	Normal	36.4	43.7		206	260		
Peekskill (4/85)	Normal						871	
Saugus	Normal				133	158		
Tulsa (Units 1 and 2)	Normal				8.39	10.3	185	
Umea, fall	Normal					178		
Umea, fall	Low temp					351		
Umea, spring	Normal					257		
WSH/DI/FF								
Quebec	110	139	235		6.45	10.9		95.4
Quebec[c]	125	467	760		0.0			
Quebec	140	436	698		2.82	4.49		99.4
Quebec	200	204	337		2.93	4.84		98.6
Wurzburg	Normal				6.38	9.08	118	
SD/FF								
Marion County	Normal					0.035	0.732	
Quebec[c]	140	371	538		0.0			
Quebec	140 & R.	454	724		1.42	2.28		99.7
Refractory								
ESP								
Philadelphia (NW1)	Normal				1,410	3,190		
Philadelphia (NW2)	Normal				453	1,160		
Starved air								
No control device								
Cattaraugus County	Normal	17.5						
Prince Edward Island	Normal	93.9	146	2,660				
Prince Edward Island	Long	94.2	152	2,540				
Prince Edward Island	High	91.1	111	1,800				
Prince Edward Island	Low	67.2	124	2,360				
ESP								
Red Wing	Normal				1,160	1,840	35,500	
RDF fired								
ESP								
Albany	Normal				9.26	11.7	264	
Hamilton-Wentworth[d]	F/None				111	157		
Hamilton-Wentworth[e]	F/Low back				3,910	3,800		
Hamilton-Wentworth	F/Back				1,020	1,180		
Hamilton-Wentworth[d]	F/Back, low front				778	1,270		
Hamilton-Wentworth[d]	H/None				222	481		
Hamilton-Wentworth[d]	H/Low back				489	918		

(continued)

TABLE 7-101. (continued)

Facility name	Test condition	Emissions upstream from control device			Emissions downstream from control device			Control efficiency, %
		$\times 10^{-10}$ gr/dscf	$\times 10^{-10}$ gr/dscf at 12% CO_2	$\times 10^{-10}$ lb/ton feed	$\times 10^{-10}$ gr/dscf	$\times 10^{-10}$ gr/dscf at 12% CO_2	$\times 10^{-10}$ lb/ton feed	
CYC/ESP Wright Pat. AFB	Normal				182	288	8,120	

[a] Outlet values which represent the average of test runs 3, 4, and 5 were used to obtain a control efficiency value for simultaneous test runs. Inlet runs 1 and 2 were not analyzed due to sampling difficulties.

[b] An apparent increase in concentration occurred across the control device; however, no reason for this increase was indicated in the test reports.

[c] A 0.0 indicates below detection limit (values of detection limit not yet received).

[d] Average of two test runs.

[e] One test run only.

TABLE 7-102. SUMMARY OF TOTAL OCTACHLORODIBENZOFURAN EMISSIONS FROM MWC FACILITIES

Facility name	Test condition	Emissions upstream from control device $\times 10^{-10}$ gr/dscf	Emissions upstream from control device $\times 10^{-10}$ gr/dscf at 12% CO_2	Emissions upstream from control device $\times 10^{-10}$ lb/ton feed	Emissions downstream from control device $\times 10^{-10}$ gr/dscf	Emissions downstream from control device $\times 10^{-10}$ gr/dscf at 12% CO_2	Emissions downstream from control device $\times 10^{-10}$ lb/ton feed	Control efficiency, %
Mass burn								
Waterwall								
ESP								
Chicago	Normal				2.62	3.51	60.6	
Hampton (1981)	Normal				341	620	10,700	
Hampton (1983)	Normal				61.2	56.9	1,270	
Hampton (1984)	Normal				481	861	10,000	
N. Andover[a,b]	Normal	10.9	13.1		225	284		
Peekskill (4/85)	Normal						32.0	
Saugus	Normal				65.1	77.3		
Tulsa (Units 1 and 2)	Normal				2.52	3.09	55.5	
Umea, fall	Normal					52.4		
Umea, fall	Low temp					121		
Umea, spring	Normal					173		
WSH/DI/FF								
Quebec[c]	110	51.2	86.2		0.0			
Quebec[c]	125	153	248		0.0			
Quebec[c]	140	102	163		0.0			
Quebec[c]	200	85.7	141		0.0			
Wurzburg	Normal				2.70	3.84	50.0	
SD/FF								
Marion County	Normal					0.157	3.30	
Quebec[c]	140	116	169		0.0			
Quebec[c]	140 & R.	119	190		0.0			
Refractory								
ESP								
Philadelphia (NW1)	Normal				91.8	208		
Philadelphia (NW2)	Normal				53.8	137		
Starved air								
No control device								
Cattaraugus County	Normal	0.306						
Prince Edward Island	Normal	17.0	26.6	460				
Prince Edward Island	Long	16.7	26.6	460				
Prince Edward Island	High	10.9	13.3	240				
Prince Edward Island	Low	16.8	31.1	620				
ESP								
Red Wing	Normal				210	334	6,450	
RDF fired								
ESP								
Hamilton-Wentworth[d]	F/None				66.9	101		
Hamilton-Wentworth[e]	F/Low back				756	743		
Hamilton-Wentworth	F/Back				156	184		
Hamilton-Wentworth[d]	F/Back, low front				156	227		
Hamilton-Wentworth[d]	H/None				178	393		
Hamilton-Wentworth[d]	H/Low back				472	874		

(continued)

TABLE 7-102. (continued)

Facility name	Test condition	Emissions upstream from control device			Emissions downstream from control device			Control efficiency, %
		$\times 10^{-10}$ gr/dscf	$\times 10^{-10}$ gr/dscf at 12% CO_2	$\times 10^{-10}$ lb/ton feed	$\times 10^{-10}$ gr/dscf	$\times 10^{-10}$ gr/dscf at 12% CO_2	$\times 10^{-10}$ lb/ton feed	
CYC/ESP								
Wright Pat. AFB	Normal				23.5	37.1	1,050	

[a] Outlet values which represent the average of test runs 3, 4, and 5 were used to obtain a control efficiency value for simultaneous test runs. Inlet runs 1 and 2 were not analyzed due to sampling difficulties.

[b] An apparent increase in concentration occurred across the control device; however, no reason for this increase was indicated in the test reports.

[c] A 0.0 indicates below detection limit (values of detection limit not yet received).

[d] Average of two test runs.

[e] One test run only.

TABLE 7-103. SUMMARY OF TETRA- THROUGH OCTACHLORODIBENZOFURAN EMISSIONS FROM MWC FACILITIES

Facility name	Test condition	Emissions upstream from control device $\times10^{-10}$ gr/dscf	$\times10^{-10}$ gr/dscf at 12% CO_2	$\times10^{-10}$ lb/ton feed	Emissions downstream from control device $\times10^{-10}$ gr/dscf	$\times10^{-10}$ gr/dscf at 12% CO_2	$\times10^{-10}$ lb/ton feed	Control efficiency, %
Mass burn								
Waterwall								
ESP								
Hampton (1981)	Normal				26,200	47,600	824,000	
Hampton (1983)	Normal				35,900	33,400	746,000	
Hampton (1984)	Normal				36,100	64,600	750,000	
N. Andover[a,b]	Normal	309	371		841	1,060		
Peekskill (4/85)	Normal						6,340	
Saugus	Normal				1,510	1,800		
Tulsa (Units 1 and 2)	Normal				55.4	67.8	1,220	
Umea, fall	Normal					1,360		
Umea, fall	Low temp					1,770		
Umea, spring	Normal					979		
WSH/DI/FF								
Quebec	110	862	1,450		6.45	10.9		99.3
Quebec[c]	125	2,780	4,490		0.0			
Quebec	140	2,910	4,670		2.82	4.49		99.9
Quebec	200	1,560	2,570		3.36	5.51		99.8
Wurzburg	Normal				85.7	122	1,580	
SD/FF								
Marion County	Normal					1.84	38.7	
Quebec[c]	140	2,090	3,010		0.0			
Quebec	140 & R.	2,480	3,970		2.58	4.14		99.9
Refractory								
ESP								
Philadelphia (NW1)	Normal				11,400	25,800		
Philadelphia (NW2)	Normal				4,810	12,500		
Starved air								
No control device								
Cattaraugus County	Normal	874						
Prince Edward Island	Normal	402	632	11,400				
Prince Edward Island	Long	433	694	11,500				
Prince Edward Island	High	347	422	6,800				
Prince Edward Island	Low	233	431	8,220				
ESP								
Red Wing	Normal				4,860	7,730	149,000	
RDF fired								
ESP								
Hamilton-Wentworth[d]	F/None				21,900	32,200		
Hamilton-Wentworth[e]	F/Low back				38,800	37,300		
Hamilton-Wentworth	F/Back				30,100	39,800		
Hamilton-Wentworth[d]	F/Back, low front[f]				40,300	55,100		
Hamilton-Wentworth[d]	H/None				18,200	40,600		
Hamilton-Wentworth[d]	H/Low back				11,500	30,200		

(continued)

TABLE 7-103. (continued)

Facility name	Test condition	Emissions upstream from control device			Emissions downstream from control device			Control efficiency, %
		$\times 10^{-10}$ gr/dscf	$\times 10^{-10}$ gr/dscf at 12% CO_2	$\times 10^{-10}$ lb/ton feed	$\times 10^{-10}$ gr/dscf	$\times 10^{-10}$ gr/dscf at 12% CO_2	$\times 10^{-10}$ lb/ton feed	
CYC/ESP								
Wright Pat. AFB	Normal				374	590	20,200	

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[a] Outlet values which represent the average of test runs 3, 4, and 5 were used to obtain a control efficiency value for simultaneous test runs. Inlet runs 1 and 2 were not analyzed due to sampling difficulties.

[b] An apparent increase in concentration occurred across the control device; however, no reason for this increase was indicated in the test reports.

[c] A 0.0 indicates below detection limit (values of detection limit not yet received).

[d] Average of two test runs.

[e] One test run only.

TABLE 7-104. SUMMARY OF TOTAL MEASURED CHLORODIBENZOFURAN EMISSIONS FROM MWC FACILITIES

Facility name	Test condition	Emissions upstream from control device $\times 10^{-10}$ gr/dscf	 $\times 10^{-10}$ gr/dscf at 12% CO_2	 $\times 10^{-10}$ lb/ton feed	Emissions downstream from control device $\times 10^{-10}$ gr/dscf	 $\times 10^{-10}$ gr/dscf at 12% CO_2	 $\times 10^{-10}$ lb/ton feed	Control efficiency, %
Mass burn								
Waterwall								
ESP								
Chicago[a]	Normal				698	934	16,400	
Hampton (1981)[b]	Normal				26,200	47,600	824,000	
Hampton (1982)[c]	Normal				1,680	1,670	35,400	
Hampton (1983)[b]	Normal				35,900	33,400	746,000	
Hampton (1984)[b]	Normal				36,100	64,600	750,000	
N. Andover[d,e]	Normal	625	752		1,120	1,410		
Peekskill (4/85)[b]	Normal						6,340	
Saugus[b]	Normal				1,510	1,800		
Tulsa (Units 1 and 2)[b]		Normal				55.4	67.8	1,220
Umea, fall[b]	Normal					1,360		
Umea, fall[b]	Low temp					1,770		
Umea, spring[b]	Normal					979		
WSH/DI/FF								
Quebec[f]	110	862	1,450		6.45	10.9		99.3
Quebec[f,g]	125	2,780	4,490		0.0			
Quebec[f]	140	2,910	4,670		2.82	4.49		99.9
Quebec[f]	200	1,560	2,570		3.36	5.51		99.8
Wurzburg[b]	Normal				85.7	122	1,580	
SD/FF								
Marion County[b]	Normal					1.84	38.7	
Quebec[f,g]	140	2,090	3,010		0.0			
Quebec[f]	140 & R.	2,480	3,970		2.58	4.14		99.9
Refractory								
ESP								
Philadelphia (NW1)[b]	Normal				11,400	25,800		
Philadelphia (NW2)[b]	Normal				4,810	12,500		
CYC								
Mayport[c]	MSW/waste oil				91.9	143	5,230	
EGB								
Pittsfield[f]	Experimental	686						
Starved air								
No control device								
Cattaraugus County[b]	Normal	874						
Dyersburg[c]	Normal	317	541	10,500				
Prince Edward Island[b]	Normal	402	632	11,400				
Prince Edward Island[b]	Long	433	694	11,500				
Prince Edward Island[b]	High	347	422	6,800				
Prince Edward Island[b]	Low	233	431	8,220				
ESP								
Red Wing	Normal				5,000	7,930	153,000	
RDF fired								
ESP								
Akron[c]	Normal				2,000	2,970	33,500	
Albany[h]	Normal				333	420	9,490	

(continued)

TABLE 7-104. (continued)

Facility name	Test condition	Emissions upstream from control device			Emissions downstream from control device			Control efficiency, %
		$\times 10^{-10}$ gr/dscf	$\times 10^{-10}$ gr/dscf at 12% CO_2	$\times 10^{-10}$ lb/ton feed	$\times 10^{-10}$ gr/dscf	$\times 10^{-10}$ gr/dscf at 12% CO_2	$\times 10^{-10}$ lb/ton feed	
Hamilton-Wentworth[b] [i]	F/None				21,900	32,200		
Hamilton-Wentworth[b] [j]	F/Low back				38,800	37,300		
Hamilton-Wentworth[b]	F/Back				30,100	39,800		
Hamilton-Wentworth[b] [i]	F/Back, low front[f]				40,300	55,100		
Hamilton-Wentworth[b] [i]	H/None				18,200	40,600		
Hamilton-Wentworth[b] [i]	H/Low back				11,500	30,200		
CYC/ESP								
Wright Pat. AFB[b]	Normal				374	590	20,200	

[a] Sum of tetra- through octachlorodibenzofuran without penta.

[b] Sum of tetra- through octachlorodibenzofuran.

[c] Tetrachlorodibenzofuran only.

[d] Outlet values which represent the average of test runs 3, 4, and 5 were used to obtain a control efficiency value for simultaneous test runs. Inlet runs 1 and 2 were not analyzed due to sampling difficulties.

[e] An apparent increase in concentration occurred across the control device; however, no reason for this increase was indicated in the test reports.

[f] Presented as polychlorodibenzofuran in test report.

[g] A 0.0 indicates below detection limit (values of detection limit not yet received).

[h] Tetra- through heptachlorodibenzofuran.

[i] Average of two test runs.

[j] One test run only.

Isomer-specific PCDF in English units

7-105 Summary of 2,3,7,8-Substituted and Total Tetrachlorodibenzofuran Emissions from MWC Facilities

7-106 Summary of 2,3,7,8-Substituted and Total Pentachlorodibenzofuran Emissions from MWC Facilities

7-107 Summary of 2,3,7,8-Substituted and Total Hexachlorodibenzofuran Emissions from MWC Facilities

7-108 Summary of 2,3,7,8-Substituted and Total Heptachlorodibenzofuran Emissions from MWC Facilities

TABLE 7-105. SUMMARY OF 2,3,7,8-SUBSTITUTED AND TOTAL TETRACHLORODIBENZOFURAN EMISSIONS FROM MWC FACILITIES

Facility name	Test condition	Emissions upstream from control device		Emissions downstream from control device	
		2,3,7,8-TCDF, $\times 10^{-10}$ gr/dscf at 12% CO_2	Total TCDF, $\times 10^{-10}$ gr/dscf at 12% CO_2	2,3,7,8-TCDF $\times 10^{-10}$ gr/dscf at 12% CO_2	Total TCDF, $\times 10^{-10}$ gr/dscf at 12% CO_2
Mass burn					
Waterwall					
ESP					
Hampton (1982)	Normal			316	1,670
Hampton (1984)	Normal			1,960	15,000
N. Andover	Normal	48.1	188	71.2	271
Saugus	Normal			102	794
Tulsa (Units 1 and 2)	Normal			12.7	31.9
Umea, fall	Normal			13.1	451
Umea, fall	Low temp			13.6	456
Umea, spring	Normal			4.19	99.6
WSH/DI/FF					
Wurzburg	Normal			1.09	41.9
SD/FF					
Marion County	Normal			0.734	1.41
Refractory					
ESP					
Philadelphia (NW1)	Normal			251	4,780
Philadelphia (NW2)	Normal			147	3,240
CYC					
Mayport	MSW/waste oil			69.9	143
Starved air					
No control device					
Cattaraugus County[a]	Normal	11.8	524		
ESP					
Red Wing	Normal			256	1,510
RDF fired					
ESP					
Albany	Normal			11.8	205

[a] Not corrected to 12 percent CO_2.

TABLE 7-106. SUMMARY OF 2,3,7,8-SUBSTITUTED AND TOTAL PENTACHLORODIBENZOFURAN EMISSIONS FROM MWC FACILITIES

		Emissions upstream from control device			Emissions downstream from control device		
Facility name	Test condition	1,2,3,7,8-PeCDF, $\times 10^{-10}$ gr/dscf at 12% CO_2	2,3,4,7,8-PeCDF, $\times 10^{-10}$ gr/dscf at 12% CO_2	PeCDF, $\times 10^{-10}$ gr/dscf at 12% CO_2	1,2,3,7,8-PeCDF, $\times 10^{-10}$ gr/dscf at 12% CO_2	2,3,4,7,8-PeCDF, $\times 10^{-10}$ gr/dscf at 12% CO_2	Total PeCDF, $\times 10^{-10}$ gr/dscf at 12% CO_2
Mass burn							
Waterwall							
ESP							
N. Andover	Normal	8.74	17.5	78.7	16.2	33.3	145
Saugus	Normal				25.8	45.4	463
Tulsa (Units 1 and 2)	Normal				2.45	4.98	14.6
Umea, fall	Normal				48.1	31.9	509
Umea, fall	Low temp				43.7	38.9	577
Umea, spring	Normal				13.1	20.5	225
WSH/DI/FF							
Wurzburg	Normal				3.67[a]	2.71	40.4
SD/FF							
Marion County	Normal				0.044	0.066	0.192
Refractory							
ESP							
Philadelphia (MW1)	Normal				511	1,250	5,280
Philadelphia (MW2)	Normal				376	463	4,490
Starved air							
ESP							
Red Wing	Normal				77.8	329	1,950

[a] Includes 1,2,3,4,8-PeCDF.

TABLE 7-107. SUMMARY OF 2,3,7,8-SUBSTITUTED AND TOTAL HEXACHLORODIBENZOFURAN EMISSIONS FROM MWC FACILITIES

		Emissions upstream from control device					Emissions downstream from control device				
Facility name	Test condition	1,2,3,4,7,8-HxCDF, $x10^{-10}$ gr/dscf at 12% CO_2	1,2,3,6,7,8-HxCDF, $x10^{-10}$ gr/dscf at 12% CO_2	1,2,3,7,8,9-HxCDF, $x10^{-10}$ gr/dscf at 12% CO_2	2,3,4,6,7,8-HxCDF, $x10^{-10}$ gr/dscf at 12% CO_2	Total HxCDF, $x10^{-10}$ gr/dscf at 12% CO_2	1,2,3,4,7,8-HxCDF, $x10^{-10}$ gr/dscf at 12% CO_2	1,2,3,6,7,8-HxCDF, $x10^{-10}$ gr/dscf at 12% CO_2	1,2,3,7,8,9-HxCDF, $x10^{-10}$ gr/dscf at 12% CO_2	2,3,4,6,7,8-HxCDF, $x10^{-10}$ gr/dscf at 12% CO_2	Total HxCDF, $x10^{-10}$ gr/dscf at 12% CO_2
Mass burn											
Waterwall											
ESP											
N. Andover	Normal	17.5	4.37	0.0		48.1	49.4	15.1	0.0		97.9
Saugus	Normal						568	34.1	0.0		304
Tulsa (Units 1 and 2)	Normal						2.93	1.18	0.481	3.15	7.96
Umea, fall	Normal						18.8[a]	19.2	4.37	13.5	178
Umea, fall	Low temp						27.1[a]	26.2	6.12	26.7	262
Umea, spring	Normal						23.6[a]	24.0	18.8	22.7	225
WSH/DI/FE											
Wurzburg	Normal						1.84[a]	2.14	0.350	2.71	26.4
SD/FF											
Marion County	Normal						0.017	0.0017	0.022	0.022	0.057
Refractory											
ESP											
Philadelphia (NW1)	Normal						1,280	3,190			12,300
Philadelphia (NW2)	Normal						489	625			3,500
Starved air											
ESP											
Red Wing	Normal						564	232	<0.054	485	2,090

[a] Includes 1,2,3,4,7,9-HxCDF.

TABLE 7-108. SUMMARY OF 2,3,7,8-SUBSTITUTED AND TOTAL HEPTACHLORODIBENZOFURAN EMISSIONS FROM MWC FACILITIES

		Emissions upstream from control device			Emissions downstream from control device		
Facility name	Test condition	1,2,3,4,6,7,8-HpCDF, $\times 10^{-10}$ gr/dscf at 12% CO_2	1,2,3,4,7,8-HpCDF, $\times 10^{-10}$ gr/dscf at 12% CO_2	Total HpCDF, $\times 10^{-10}$ gr/dscf at 12% CO_2	1,2,3,4,6,7,8-HpCDF, $\times 10^{-10}$ gr/dscf at 12% CO_2	1,2,3,4,7,8,9-HpCDF, $\times 10^{-10}$ gr/dscf at 12% CO_2	Total HpCDF, $\times 10^{-10}$ gr/dscf at 12% CO_2
Mass burn							
Waterwall							
ESP							
Tulsa (Units 1 and 2)	Normal				7.82	0.918	10.3
WSH/DI/FF							
Wurzburg	Normal				7.47	0.262	9.08
SD/FF							
Marion County	Normal				0.031	0.044	0.035
Refractory							
ESP							
Philadelphia (NW1)	Normal				2,240	170	3,190
Philadelphia (NW2)	Normal				822	78.7	1,160
Starved air							
ESP							
Red Wing	Normal				1,220	90.0	1,840

Other organic pollutants in English units

7-109 Summary of Polychlorinated Biphenyls Emissions From MWC Facilities

7-110 Summary of Formaldehyde Emissions From MWC Facilities

7-111 Summary of Benzo-a-pyrene Emissions From MWC Facilities

7-112 Summary of Total Measured Chlorinated Benzene Emissions From MWC Facilities

7-113 Summary of Total Measured Chlorinated Phenol Emissions From MWC Facilities

TABLE 7-109. SUMMARY OF POLYCHLORINATED BIPHENYLS EMISSIONS FROM MWC FACILITIES

Facility name	Test condition	Emissions upstream from control device			Emissions downstream from control device			Control efficiency, %
		$\times 10^{-10}$ gr/dscf	$\times 10^{-10}$ gr/dscf at 12% CO_2	$\times 10^{-10}$ lb/ton feed	$\times 10^{-10}$ gr/dscf	$\times 10^{-10}$ gr/dscf at 12% CO_2	$\times 10^{-10}$ lb/ton feed	
Mass burn								
Waterwall								
ESP								
Chicago	Normal				184	246	4,240	
Hampton (1981)	Normal				3,130	5,700	99,100	
Hampton (1983)	Normal				2,930	2,720	60,800	
WSH/DI/FF								
Quebec	110	90.7	154		25	42.2		72.4
Quebec	125	1,910	3,100		16.8	27.2		99.1
Quebec[a]	140	90.2	144		0.0			
Quebec	200	54.5	86.6		24.1	39.6		53.7
SD/FF								
Quebec[a]	140	56.4	81.8		0.0			
Quebec[a]	140 & R.	60.9	97.7		0.0			
Starved air								
No control device								
Prince Edward Island	Normal	2,280	3,560	68,300				
Prince Edward Island	Long	161	257	4,900				
Prince Edward Island	Low	302	560	11,500				
RDF fired								
ESP								
Albany	Normal				941	1,190	26,800	
Hamilton-Wentworth[b]	F/None				2,290,000	3,330,000		
Hamilton-Wentworth[c]	F/Low back				677,000	656,000		
Hamilton-Wentworth	F/Back				2,630,000	3,120,000		
Hamilton-Wentworth[b]	F/Back, low front				948,000	1,280,000		
Hamilton-Wentworth[b]	H/None				1,300,000	2,910,000		
Hamilton-Wentworth[b]	H/Low back				1,760,000	2,860,000		

[a] A 0.0 indicates below detection limit (values of detection limit not yet received).
[b] Average of two test runs.
[c] One test run only.

TABLE 7-110. SUMMARY OF FORMALDEHYDE EMISSIONS FROM MWC FACILITIES

		Emissions upstream from control device			Emissions downstream from control device			
Facility name	Test condition	$\times 10^{-6}$ gr/dscf	$\times 10^{-6}$ gr/dscf at 12% CO_2	$\times 10^{-6}$ lb/ton feed	$\times 10^{-6}$ gr/dscf	$\times 10^{-6}$ gr/dscf at 12% CO_2	$\times 10^{-6}$ lb/ton feed	Control efficiency, %
Mass burn								
Waterwall								
ESP								
Hampton (1982)	Normal				752	745	15,800	
Starved air								
No control device								
Dyersburg	Normal	8.30	14.2	275				
RDF fired								
ESP								
Akron	Normal				51.1	75.7	856	
Albany	Normal				56.0	70.8	1,600	

TABLE 7-111. SUMMARY OF BENZO-a-PYRENE EMISSIONS FROM MWC FACILITIES

Facility name	Test condition	Emissions upstream from control device			Emissions downstream from control device			Control efficiency, %
		$\times 10^{-10}$ gr/dscf	$\times 10^{-10}$ gr/dscf at 12% CO_2	$\times 10^{-10}$ lb/ton feed	$\times 10^{-10}$ gr/dscf	$\times 10^{-10}$ gr/dscf at 12% CO_2	$\times 10^{-10}$ lb/ton feed	
Mass burn								
Waterwall								
ESP								
Hampton (1982)	Normal				39,500	39,100	831,000	
Hampton (1983)	Normal				52,400	48,800	1,090,000	
RDF fired								
ESP								
Albany	Normal				91,800	116,000	2,620,000	

TABLE 7-112. SUMMARY OF TOTAL MEASURED CHLORINATED BENZENE EMISSIONS FROM MWC FACILITIES

Facility name	Test condition	Emissions upstream from control device $\times10^{-10}$ gr/dscf	Emissions upstream from control device $\times10^{-10}$ gr/dscf at 12% CO_2	Emissions upstream from control device $\times10^{-10}$ lb/ton feed	Emissions downstream from control device $\times10^{-10}$ gr/dscf	Emissions downstream from control device $\times10^{-10}$ gr/dscf at 12% CO_2	Emissions downstream from control device $\times10^{-10}$ lb/ton feed	Control efficiency, %
Mass burn								
Waterwall								
ESP								
Chicago	Normal	8,740	11,500	202,000	7,730	10,300	178,000	10.2
Hampton (1981)	Normal				181,000	329,000	568,000	
Hampton (1982)	Normal				1,320,000	1,310,000	27,800,000	
Hampton (1984)	Normal				198,000	355,000	4,120,000	
WSH/DI/FF								
Quebec	110	35,800	60,400		1,740	2,930		95.1
Quebec	125	49,300	80,000		818	1,320		98.3
Quebec	140	34,100	54,700		645	1,030		98.1
Quebec	200	21,000	34,500		7,910	12,900		62.4
Wurzburg	Normal				3,480	5,420	73,900	
SD/FF								
Quebec	140	33,500	48,400		254	368		99.2
Quebec	140 & R.	43,300	69,400		525	836		98.8
Starved air								
No control device								
Prince Edward Island	Normal	12,300	19,200	360,000				
Prince Edward Island	Long	8,750	14,000	256,000				
Prince Edward Island	High	14,500	17,600	322,000				
Prince Edward Island	Low	11,700	21,700	440,000				
RDF fired								
ESP								
Hamilton-Wentworth[a]	F/None				303,000	441,000		
Hamilton-Wentworth[b]	F/Low back				203,000	196,000		
Hamilton-Wentworth	F/Back				152,000	181,000		
Hamilton-Wentworth[a]	F/Back, low front				147,000	197,000		
Hamilton-Wentworth[a]	H/None				105,300	236,000		
Hamilton-Wentworth[a]	H/Low back				99,200	161,000		
CYC/ESP								
Wright Pat. AFB	Normal				3,940	6,220	176,000	

[a] Average of two test runs.

[b] One test run only.

TABLE 7-113. SUMMARY OF TOTAL MEASURED CHLORINATED PHENOL EMISSIONS FROM MWC FACILITIES

Facility name	Test condition	Emissions upstream from control device			Emissions downstream from control device			Control efficiency, %
		$\times 10^{-10}$ gr/dscf	$\times 10^{-10}$ gr/dscf at 12% CO_2	$\times 10^{-10}$ lb/ton feed	$\times 10^{-10}$ gr/dscf	$\times 10^{-10}$ gr/dscf at 12% CO_2	$\times 10^{-10}$ lb/ton feed	
Mass burn								
Waterwall								
ESP								
Chicago[a]	Normal	12,800	16,800	294,000	15,600	20,900	360,000	
Hampton (1981)	Normal				533,000	969,000	16,800,000	
Hampton (1984)	Normal				935,000	1,670,000	19,400,000	
WSH/DI/FF								
Quebec	110	83,700	141,000		2,340	3,950		97.2
Quebec	125	66,700	108,000		737	1,200		98.9
Quebec	140	79,500	127,000		951	1,530		98.8
Quebec	200	52,000	85,300		23,100	38,000		55.6
SD/FF								
Quebec	140	69,800	101,000		747	1,090		98.9
Quebec	140 & R.	27,500	43,800		1,090	1,730		96.0
Starved air								
No control device								
Prince Edward Island	Normal	12,200	19,300	368,000				
Prince Edward Island	Long	10,300	16,800	300,000				
Prince Edward Island	High	9,720	12,000	216,000				
Prince Edward Island	Low	15,600	29,300	580,000				
RDF fired								
ESP								
Hamilton-Wentworth[b]	F/None				354,000	516,000		
Hamilton-Wentworth[c]	F/Low back				156,000	151,000		
Hamilton-Wentworth	F/Back				179,000	212,000		
Hamilton-Wentworth[b]	F/Back, low front				68,200	91,800		
Hamilton-Wentworth[b]	H/None				318,000	712,000		
Hamilton-Wentworth[b]	H/Low back				236,000	384,000		
CYC/ESP								
Wright Pat. AFB	Normal				39,700	62,700	1,770,000	

[a] An increase in concentration occurred across the control device; however, the difference between inlet and outlet values within the imprecision associated with the sampling and analysis techniques.

[b] Average of two test runs.

[c] One test run only.

Supplementary tables in English units

7-114 Summary of Supplementary Chlorodibenzo-p-dioxin Emissions From MWC Facilities

7-115 Summary of Supplementary Chlorodibenzofuran Emissions From MWC Facilities

7-116 Summary of Supplementary Metals Emissions From MWC Facilities

TABLE 7-114. SUMMARY OF SUPPLEMENTARY CHLORODIBENZO-p-DIOXIN EMISSIONS FROM MWC FACILITIES

Facility name	Test condition	2,3,7,8, $\times10^{-10}$ gr/dscf	Tetra, $\times10^{-10}$ gr/dscf	Penta, $\times10^{-10}$ gr/dscf	Hexa, $\times10^{-10}$ gr/dscf	Hepta, $\times10^{-10}$ gr/dscf	Octa, $\times10^{-10}$ gr/dscf	Total measured, $\times10^{-10}$ gr/dscf
Mass burn								
Waterwall/ESP								
Iserlohn	Normal	0.061	4.51				795	800[a]
Montreal (1982)	Normal		0.004	0.017	0.013	0.013	0.009	0.057[b]
Montreal (1983)	Normal		0.393	0.411	0.590	0.629	1.23	3.26[b]
Quebec (1981)	Normal		17.9	63.8	67.7	53.3	7.43	210[b]
Umea (1984)	Normal	2.19	188	232	140	78.7	52.4	690[b]
Umea (1985)	Normal	0.437	43.7	214	240	245	232	975[b]
Zurich/Josephstrasse	Normal	0.743	19.2	52.4	118	114	236	538[b]
Waterwall/DS/ESP								
Hamburg/Stapelfeld	Normal	0.437	26.2				48.1	184[c]
MVA-I Borsigstrasse	Normal	0.874	109				56.8	660[c]
MVA-II Stellinger M.	Normal	3.06	83.0				65.6	498[c]
Waterwall/CYC/DI/ESP/FF								
Malmo	Normal	0.044	0.655	0.655				1.31[d]
Waterwall/DS/FF								
Avg Borsigstrasse	Normal	0.087	45.9				249	621[c]
Refractory/SPRAY/ESP								
Toronto I	Normal		244	333	1,640	1,810	380	4,410[b]
Refractory/ESP								
Brasschaat	Normal	13.1	175	149	232	293	669	1,520[b]
Harelbeke	Normal	4.24	87.4	1,730	808	900	883	4,410[b]
Linkoping	Normal	0.109	1.97					1.97[e]
Stuttgart	Normal	1.75	84.8	149	148	100	42.8	524[b]
Zaanstad	Normal		250	1,010	1,920	1,520	1,970	6,690[b]
Refractory/								
Beveren	Normal		15.7	28.4	153	382	546	1,130[b]
Milan I	Normal	8.74	66.9				3,510	3,580[a]
Milan II	Normal		0.874				494	495[a]
Starved air								
None								
Lake Cowichan	Normal		18.4	208	437	202	6.07	870[b]
CS/ESP								
Schio	Processed		38.9					38.9[e]
Schio	Unprocessed		7.87					7.87[e]
Fluid bed								
FF								
Eskjo	RDF	2.19	49.4			138	77.3	264[f]

[a] Sum of tetra- and octachlorodibenzo-p-dioxin emissions.

[b] Sum of tetra- through octachlorodibenzo-p-dioxin emissions.

[c] Sum of tri- through octachlorodibenzo-p-dioxin emissions.

[d] Sum of tetra- and pentachlorodibenzo-p-dioxin emissions.

[e] Tetrachlorodibenzo-p-dioxin emissions only.

[f] Sum of tetra-,hepta, and octachlorodibenzo-p-dioxin emissions.

TABLE 7-115. SUMMARY OF SUPPLEMENTARY CHLORODIBENZOFURAN EMISSIONS FROM MWC FACILITIES

Facility name	Test condition	2,3,7,8, x10^{-10} gr/dscf	Tetra, x10^{-10} gr/dscf	Penta, x10^{-10} gr/dscf	Hexa, x10^{-10} gr/dscf	Hepta, x10^{-10} gr/dscf	Octa, x10^{-10} gr/dscf	Total measured, x10^{-10} gr/dscf
Mass burn								
Waterwall/ESP								
Iserlohn	Normal	0.918	83.9				180	264[a]
Montreal (1982)	Normal		0.009	0.031	0.022	0.017	0.009	0.087[b]
Montreal (1983)	Normal		0.782	0.673	0.415	0.275	0.223	2.37[b]
Quebec (1981)	Normal		201	156	170	36.7	2.80	568[b]
Umea (1984)	Normal	10.9	376	424	144	149	43.7	1,140[b]
Umea (1985)	Normal	3.72	83.0	188	188	214	144	817[b]
Zurich/Josephstrasse	Normal		105	131	87.4	61.2	39.3	424[b]
Waterwall/DS/ESP								
Hamburg/Stapelfeld	Normal	5.24	162				8.74	476[c]
MVA-I Borsigstrasse	Normal	13.1	284				13.1	699[c]
MVA-II Stellinger M.	Normal	17.5	555				8.74	1,410[c]
Waterwall/CYC/DI/ESP/FF								
Malmo	Normal	2.19	8.24	13.1	114			135[d]
Waterwall/DS/FF								
Avg Borsigstrasse	Normal	24.0	323				111	798[c]
Refractory/SPRAY/ESP								
Toronto I	Normal		962	735	1,500	992	259	4,460[b]
Refractory/ESP								
Brasschaat	Normal		857	822	961	1,630	1,890	6,160[b]
Harelbeke			507	913	153	1,470	891	3,940[b]
Linkoping	Normal	2.62	18.6	21.9	739			779[d]
Stuttgart	Normal	16.6	548	532	58.1	88.7	23.6	1,250[b]
Zaanstad	Normal		704	1,190	2,310	1,280	295	5,780[b]
Refractory/								
Beveren	Normal		69.9	144	1,390	208	175	1,990[b]
Milan I	Normal						2,550	2,550[e]
Milan II	Normal						397	397[e]
Starved air								
None								
Lake Cowichan	Normal		156	319	1,110	182	4.68	1,770[b]
CS/ESP								
Schio	Processed		104					104[f]
Schio	Unprocessed		28.8					28.8[f]
Fluid bed								
FF								
Eskjo	RDF		1,430	233	261	121	53.3	2,100[b]

[a] Sum of tetra- and octachlorofuran emissions.

[b] Sum of tetra- thorugh octachlorofuran emissions.

[c] Sum of tri- through octachlorofuran emissions.

[d] Sum of tetra-,penta- and hexachlorofuran emissions.

[e] Octachlorofuran emissions only.

[f] Tetrachlorofuran emissions only.

TABLE 7-116. SUMMARY OF SUPPLEMENTARY METALS EMISSIONS FROM MWC FACILITIES

Facility name	Test condition	Arsenic, $\times 10^{-10}$ gr/dscf	Beryllium, $\times 10^{-10}$ gr/dscf	Cadmium, $\times 10^{-10}$ gr/dscf	Total chromium, $\times 10^{-10}$ gr/dscf	Lead, $\times 10^{-10}$ gr/dscf	Mercury, $\times 10^{-10}$ gr/dscf	Nickel, $\times 10^{-10}$ gr/dscf
Mass burn								
Waterwall/ESP								
Avesto, Sweden	Pilot, inlet			0.166		3.93	0.983	
Avesto, Sweden	Pilot, outlet			0.105		2.97	0.122	
MVA Lausanne, Switzerland[a]	Normal, outlet			0.175		3.93	0.524	
MVA Munich	Normal, inlet			5.64		92.2	0.350-1.97	
MVA Munich	Normal, outlet			0.087		1.05	0.219-0.874	
Waterwall/								
Issy-les-Moulineaux	Normal, outlet			0.306			0.057	
Saint-ouen	Normal, outlet			4.85		189	2.27	

[a] Datum was reported in mg/Nm^3 at 11 percent O_2.

SUPPLEMENT A

AVAILABLE MWC EMISSION TEST REPORTS AND RELATED REFERENCES

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SUPPLEMENT B

SUMMARY OF SYMBOLS, ACRONYMS, ABBREVIATIONS, AND UNITS

Summary of Symbols, Acronyms, Abbreviations, and Units

Chemical Symbols and Acronyms

Symbol	Meaning
$AgNO_3$	Silver nitrate
As	Arsenic
BaP	Benzo-a-pyrene
Be	Beryllium
CaO	Calcium oxide
$Ca(OH)_2$	Calcium hydroxide
Cd	Cadmium
ClB	Chlorinated benzenes
ClP	Chlorinated phenols
CO	Carbon monoxide
CO_2	Carbon dioxide
Cr	Chromium
H_2O_2	Hydrogen peroxide
H_2SO_4	Sulfuric acid
HCl	Hydrogen chloride
HF	Hydrogen fluoride
Hg	Mercury
HNO_3	Nitric acid
HpCDD	Heptachlorodibenzo-p-dioxin
HpCDF	Heptachlorodibenzofuran
HxCDD	Hexachlorodibenzo-p-dioxin
HxCDF	Hexachlorodibenzofuran
$KMnO_4$	Potassium permanganate
KOH	Potassium hydroxide
NaOH	Sodium hydroxide
Ni	Nickel
NO_x	Nitrogen oxides
O_2	Oxygen
OCDD	Octachlorodibenzo-p-dioxin
OCDF	Octachlorodibenzofuran
Pb	Lead
PCB	Polychlorinated biphenyls
PCDD	Polychlorinated dibenzo-p-dioxins
PCDF	Polychlorinated dibenzofurans
PeCDD	Pentachlorodibenzo-p-dioxin
PeCDF	Pentachlorodibenzofuran

(continued)

Chemical Symbols and Acronyms (continued)

Symbol	Meaning
SO_2	Sulfur dioxides
SO_3	Sulfate ion
TCDD	Tetrachlorodibenzo-p-dioxin
TCDF	Tetrachlorodibenzofuran
Zn	Zinc

Other Symbols

Symbol	Meaning
AA	Atomic absorption spectrophotometry
ASME	American Society of Mechanical Engineers
CEM	Continuous emission monitors
CF	Conversion factor
CFR	Code of Federal Regulation
CYC	Cyclone
DBA	Deutshe Babcock Anlagen
DCPES	Direct current plasma emission spectrometry
DI	Dry injection
DS	Dry scrubber
DSC	Dry standard conditions
ECD	Electron capture detection
EGB	Electrostatic granular bed
EF	Emission factor
ESP	Electrostatic precipitator
FAA	Flameless atomic absorption
FD	Forced draft
FF	Fabric filter
FID	Flame ionization detector
GC/ECD	Gas chromatography/electron capture detection
GC/IR	Gas chromatography/infrared
GC	Gas chromatography
GC/MS	Gas chromatography/mass spectroscopy
HPLC	High performance liquid chromatography
HRGC	High resolution gas chromatography
HRMS	High resolution mass spectroscopy
ICAPS	Inductively coupled argon plasma spectrophotometry
IC	Ion chromatography
ID	Induced draft
INA	Instrumental neutron activation
LREL	Lowest reported emission level
M5	EPA Reference Method 5 for particulate matter
MM5	Modified Method 5
M6	EPA Reference Method 6 for acid gases
M6C	EPA Reference Method 6C for sulfur dioxide
M7	EPA Reference Method 7 for nitrogen oxides
M7E	EPA Reference Method 7E for nitrogen oxides

(continued)

Other Symbols (continued)

Symbol	Meaning
M8	EPA Reference Method 8 for sulfur dioxide and sulfates
M9	EPA Reference Method 9 for opacity
M10	EPA Reference Method 10 for carbon monoxide
M12	EPA Reference Method 12 for lead
M13	EPA Reference Method 13 for fluoride emissions
M13A	EPA Reference Method 13A for fluoride emissions
M13B	EPA Reference Method 13B for fluoride
M17	EPA Reference Method 17 for particulate emissions
M25	EPA Reference Method 25 for total organics
M101	EPA Reference Method 101 for mercury
M101A	EPA Reference Method 101A for mercury
M104	EPA Reference Method 104 for beryllium
M108	EPA Reference Method 108 for arsenic
M245.1	EPA Reference Method 245.1 for mercury
M325.3	EPA Reference Method 325.3 for hydrogen chloride
MID	Multiple ion detection
MS	Mass spectroscopy
MSW	Municipal solid waste
MWC	Municipal waste combustor
NAA	Neutron activation analysis
NBS	National Bureau of Standards
NDIR	Nondispersive infrared spectrophotometry
NDUV	Nondispersive ultraviolet spectrophotometry
PC	Personal computer
PM	Particulate matter
QA	Quality assurance
QC	Quality control
RDF	Refuse-derived fuel
S&A	Sampling and analysis
SASS	Source assessment sampling system
SCA	Specific collection area
SD	Spray dryer
SIE	Specific ion electrode
SIM	Selected ion monitoring
SSMS	Spark source mass spectroscopy
SWRC	Solid waste reduction center

(continued)

Other Symbols (continued)

Symbol	Meaning
THC	Total hydrocarbons
UV	Ultraviolet
VOC	Volatile organic compounds
WPAFB	Wright-Patterson Air Force Base
WS	Wet scrubber
WSH	Water spray humidifier
XRF	X-ray fluorescence

Units

Symbol	Meaning
acf	Actual cubic feet
acfm	Actual cubic feet per minute
am^3	Actual cubic meters
atm	atmoshere
Btu	British thermal unit
°C	Degrees celsius
d	Day
dscf	Dry standard cubic feet
°F	Degrees fahrenheit
ft	Feet
g	Grams
gal	Gallons
gr	Grains
h	Hour
in.	inches
kcal	Kilocalorie
kg	Kilograms
kJ	Kilojoules
kPa	Kilopascal
ℓ	Liter
lb	Pounds
ℓpm	Liters per minute
m	Meter
M	Molar
mg	Milligrams
Mg	Megagrams
min	Minute
MJ	Megajoules
mℓ	Milliliter
MW	Megawatt
ng	Nanograms
Nm^3	Normal cubic meter
ppm	Parts per million
ppmdv	Parts per million dry volume
psig	Pounds per square inch gauge
rph	Revolutions per hour
rpm	Revolutions per minute
s	Second
scfm	Standard cubic feet per minute
w.c.	Water column
µg	Micrograms

SUPPLEMENT C

DATA TRANSFER LOG FORMS

ID ________________________________ Ref#________ By ______
****

Incinerator Type/Mfg ________________________________

Control Device Type/Mfg ________________________________

Comments: ________________________________

____

Particulate Sizing on Pages ________________________________

TOXIC METALS EMISSIONS DATA

Process Measurements						Runs				
	Page	Table	Location	Units	1	2	3	4	5	6
Feed Rate	____	____	____	____	____	____	____	____	____	____
Flow Rate	____	____	____	____	____	____	____	____	____	____
O_2	____	____	____	____	____	____	____	____	____	____
CO_2	____	____	____	____	____	____	____	____	____	____
Emissions										
Inlet	____	____	As	____	____	____	____	____	____	____
	____	____	Be	____	____	____	____	____	____	____
	____	____	Cd	____	____	____	____	____	____	____
	____	____	Cr	____	____	____	____	____	____	____
	____	____	Pb	____	____	____	____	____	____	____
	____	____	Hg	____	____	____	____	____	____	____
	____	____	Ni	____	____	____	____	____	____	____
Outlet	____	____	As	____	____	____	____	____	____	____
	____	____	Be	____	____	____	____	____	____	____
	____	____	Cd	____	____	____	____	____	____	____
	____	____	Cr	____	____	____	____	____	____	____
	____	____	Pb	____	____	____	____	____	____	____
	____	____	Hg	____	____	____	____	____	____	____
	____	____	Ni	____	____	____	____	____	____	____

ACID GAS EMISSIONS DATA

Process Measurements					Runs					
	Page	Table	Location	Units	1	2	3	4	5	6
Feed Rate										
Flow Rate										
O_2										
CO_2										
Emissions										
Inlet			H_2SO_4							
			HCl							
			HF							
Outlet			H_2SO_4							
			HCl							
			HF							

CRITERIA POLLUTANTS EMISSIONS DATA

Process Measurements					Runs					
	Page	Table	Location	Units	1	2	3	4	5	6
Feed Rate										
Flow Rate										
O_2										
CO_2										
Emissions										
Inlet			PM							
			NO_x							
			SO_2							
			CO							
Outlet			PM							
			NO_x							
			SO_2							
			CO							

TOXIC ORGANICS EMISSIONS DATA

Process Measurements

	Page	Table	Location	Units	1	2	3	4	5	6
Feed Rate										
Flow Rate										
O_2										
CO_2										

Emissions (Units:______)

	Inlet						Outlet					
	Page	Table	1	2	3	ave	Page	Table	1	2	3	ave
2378 TCDD												
2378 TCDF												
Tot TCDD												
Tot TCDF												
Tot PCDD												
Tot PCDF												
Tot HxCDD												
Tot HxCDF												
Tot HpCDD												
Tot HpCDF												
Tot OcCDD												
Tot OcCDF												
Tet-OctCDD												
Tet-OctCDF												
Tot PCB												
Formaldehyd												
Tot ClB												
Tot ClP												
BaP												
Benzene												